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PRODUCT ENGINEERING

McGRAW-HILL WEEKLY FOR DESIGN ENGINEERS · MARCH 20, 1961

AUTOMATIC ASSEMBLY *starts with connectors on paper tape* . . . see page 3

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March 20, 1961 Vol. 32, No. 12

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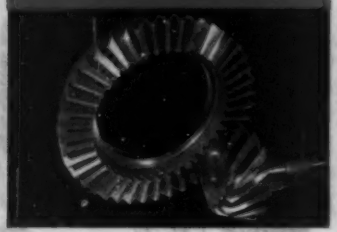

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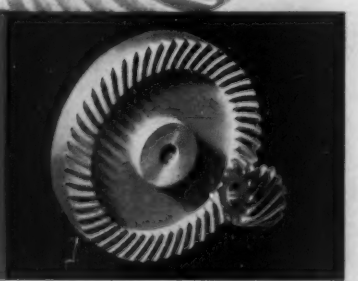

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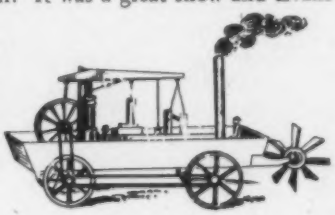
INTERESTING TO NOTE

On our cover—another new development in automation, Berg Mfg Corp's machine for producing components for printed circuit boards. This one inserts gold-plated clips on a paper tape, following a programed pattern—first a row of short clips, then a row of long ones. The clips are then staked to the circuit boards. (See news photos on page 15 for details.)

The first truly automatic industrial operation in this country was Oliver Evans' famous granary. Built in the late 1790s, Evans' mill would accept grain at one end, process it automatically and deliver flour at the other end. But Evans was too many years ahead of his time and his automatic mill, although patented, was never accepted. Evans' mill was but one of his many ideas. In 1773, he began work on a steam-driven horseless carriage. Within a few years, Evans had constructed a 15-ton, 30-foot-long craft he called an "Orukter Amphibolas." It was the world's first amphibious steam-driven vehicle and the first self-powered wheeled vehicle in America, but the public reacted coolly to the Orukter (as coolly as it did later to the automatic mill). Evans dismayed? Not he. He went right on developing a more efficient steam engine to power his amphibious craft. His sources of revenue were a small dry-goods store and a foundry he owned and operated with the assistance of his wife. At one time, when funds were low, Evans exhibited the Orukter to Philadelphians for 25¢ apiece.

His search for a better steam engine led him to build "a small engine for a mill to grind plaster of paris." He started with a thousand dollars for R & D, but by the time he had a working model, he had spent more than three thousand. While in the process of developing this high-pressure engine, he brought his plans to Robert Patterson, professor of mathematics at the Univ of Pennsylvania, who told Evans that although his principles were new, they were sound. Benjamin Latrobe of the Philosophical Society also studied Evans' plans; this expert, however, labeled them "absurd."

In 1803, the Evans steam engine was built and taken to Philadelphia's Market St where it was harnessed to a stone crusher. It ground 12 tons of plaster in 24 hr. He next applied it to a stone saw and was able to cut through 100 ft of marble in 12 hr. It was a great show and Evans "frequently heard spectators inquire if the power coulde be applied to saw timber as well as stone, to grind grain, propel boats, etc; and though I (Evans) an-



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swered in the affirmative—still they doubted."

In 1804, three years before Fulton's Clermont steamed up the Hudson, Evans was given a contract for a steam engine to be used in dredging Philadelphia's harbor. He built the engine 16 miles upriver, in a shed a mile and a half from the water. He put his engine on a crude 15½-ton scow equipped with land wheels and water wheels. The huge machine lumbered over land, slid into the river, steamed downstream, climbed back on dry land, circled a few blocks and stopped by the docks. Thousands of spectators were amazed by this demonstration.

Learning About Seals From Seals

Choosing the right seal, the subject of the Special Report on 57, is a problem that has plagued designers for years. Sealing the cabin of a space vehicle or the container for a lubricated bearing is done differently but basically the problem is the same. A seal must be effective.

In the early days of canning, for example, a poorly sealed container often caused spoilage, and in some cases food poisoning. During the latter stages of the French Revolution, a crude method of preserving food in airtight glass jars enabled Napoleon's armies to be fed a more varied diet. This helped prevent scurvy, a disease then common among his troops who were not getting sufficient amounts of vitamin C; but it had some bad effects, too. Some of the seals leaked and certain bacteria, molds and spores caused decay that poisoned some soldiers.

Engineers studying the effects of seals under pressure are now being aided by a different type of seal—the mammalian variety. Marine biologists have found that these arctic aquatics are able to resist pressures at depths of more than 1500 ft. A man diving to such a depth without special apparatus would be crushed to death. It's been found that seals are able to slow their heart rates as they descend, from a normal 180 beats per minute to as low as 20. Discovering how the seal can withstand these pressures may help protect astronauts from the great pressure drop that would occur if the non-animal seal on their space capsule proved inadequate.

—Benedict A Leerburger Jr

SIDELIGHT

With the opening day of the baseball season around the corner, armchair pitchers can renew their annual discussion, "Does a baseball really curve?" Thanks to a paper presented before a recent meeting of the American Physical Society, armchair pitchers now have "scientific evidence." The paper, "Aerodynamics of the Spinning Baseball," by Paul Kirkpatrick, discusses the work of a Japanese scientist and the Director Emeritus of our National Bureau of Standards. The pair found "that a ball pitched at moderate speed with a spin of 30 rev/sec about a vertical axis will depart from its original direction of advance and be about a foot and a half off course when it passes the plate, and this is apparently about as much curve as may be expected unless baseballs or pitchers should be radically redesigned."

Now that this problem is solved, another vital question remains—what does a knuckle ball really do?

NEXT WEEK IN PRODUCT ENGINEERING

. . . **Which Instrument Motor for the Job?**
When choosing a fractional or subfractional motor for instrument use, many factors will determine the type of motor you need.

. . . **Cheapest Way to Produce Metal Parts**
This study shows that the choice must depend upon such factors as complexity of the part, quantity produced and cost of material.

. . . **New Constant-force Spring Systems**
They have already improved the packaging of delicate instruments, and they open the way to better vibration mounts.

. . . **Finding Liquid Volume in Ellipsoidal Tanks**
Nomograph solves for special versions and a sphere as well as the pure ellipsoid.

. . . **New Instrument Grades Polished Metal Surfaces**
Quantitative readings are faster and more reliable than those obtained with subjective, visual methods.

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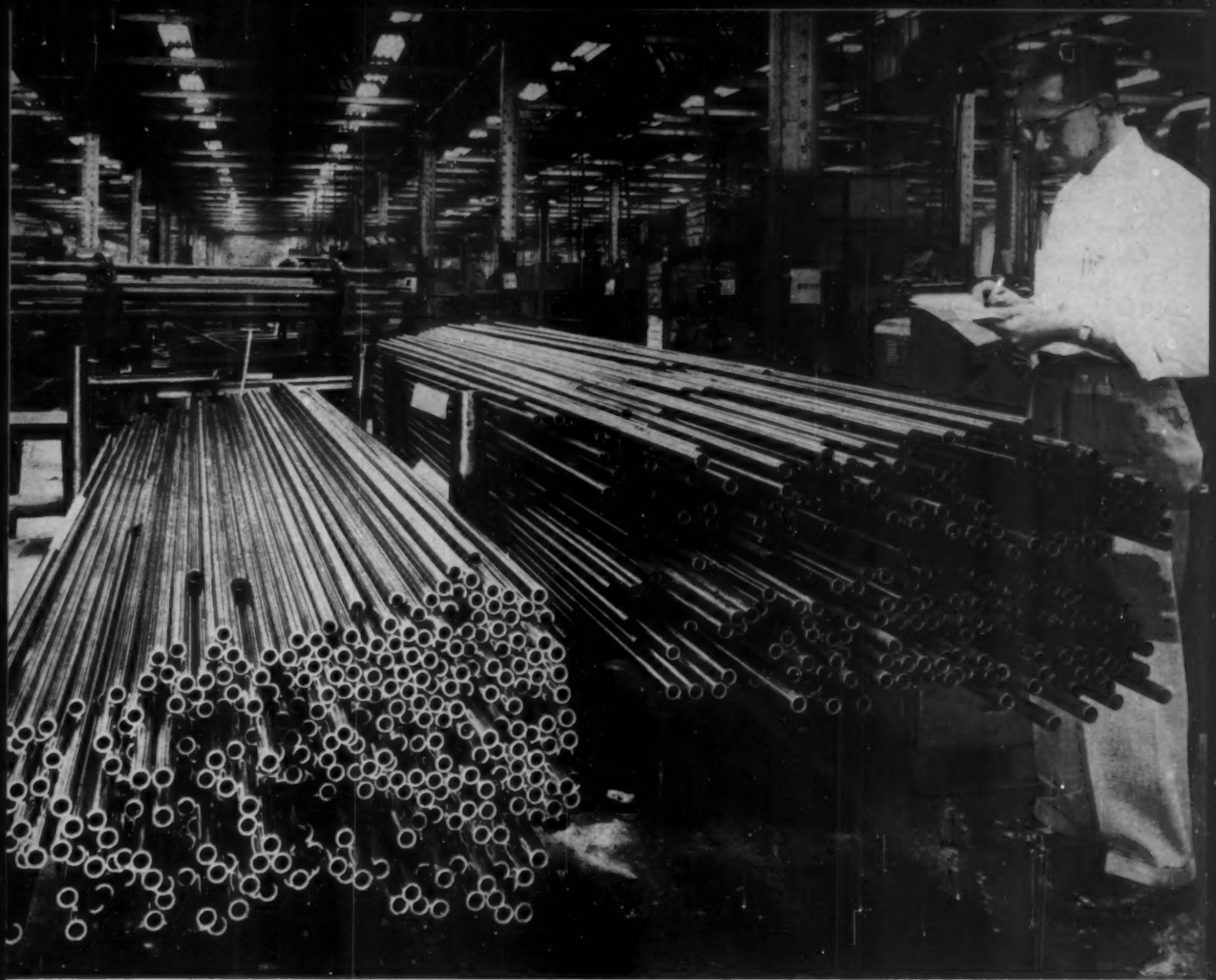

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It takes plenty of machine time to drill and machine the holes in 6,500,000 piston pins a year. That's what one major auto company* had to do . . . *until* the switch to USS National Seamless Steel Mechanical Tubing. By eliminating the need to drill holes in the bar stock, the company got rid of six chuckers formerly used for drilling, saved time as well as the power they consumed and the space they occupied. ☐ USS National Seamless Tubing has dimensional accuracy. It has no hard or soft spots. It's made by people who know more about seamless tubing than any other manufacturer in the world. You can choose from a complete range of sizes and steel grades. Find out how USS National Seamless Mechanical Tubing can be most effectively applied to your designs. Contact your nearest National Tube Distributor soon.

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WHAT'S HAPPENING IN RESEARCH...

Developing conductors for high-temperature service

To meet the need for flexible electrical conductors—both windings and cables—that are serviceable at 500 F and above, a host of new approaches are being tried (*PE*—Feb 20, p 6; Mar 6, p 9 and Mar 13, p 9). For miniature lead wire, glass and heat-resistant resins and enamels are being combined in new types of coatings and sheathings. For coil windings, plated wire and electrophoretically deposited coatings are under test. New approaches are being tried for coaxial cable as well. Here, an extruded boron nitride coating, bonded with phosphates and fluoro-organics, looks especially promising.

Reporting on an extensive development and evaluation program for the Bureau of Ships, which included tests of sprayed alumina and extruded clay and mica compositions, Armour Research Foundation says the boron nitride-insulated cable showed a dielectric constant of 2.5 and a dissipation factor of less than 0.01 at frequencies in the 300-kc range and temperatures of 660 and 930 F. Flexibility is good, too. The cable can be spooled on 0.875-in. mandrels without deterioration of electrical properties.

In contrast, the alumina coatings, which were applied by spraying, were much too porous and brittle; clay coatings, while readily extruded, did not meet electrical requirements; and mica required organic binders which resulted in a spongy structure. The boron nitride itself was not too easy to apply. But, with the aid of suitable phosphate binders, satisfactory coatings were produced. Further research, Armour says, should make it possible to develop still better formulations and extrusion techniques.

Research ideas to solve fabrication woes

New approaches to casting and heat treatment to get around the fabrication problems that now limit special materials applications are suggested by E. A. Kachik of DuPont Engineering Research Laboratory.

For example, casting under pressure in an atmosphere of desirable-but-volatile elements might get around one present-day limitation of vacuum melting: loss through vaporization of essential constituents.

In the area of heat treatment, Kachik notes, explosive hardening, first applied to manganese steels (*PE*—Dec 15 '58, p 5) is now being extended to plain carbon steel. But, he admitted in an AIChE report, the increase in hardness and tensile strength (equivalent in effect to an 90% reduction by cold working) is accompanied by an increase in transition temperature and a loss of impact strength. However, he believes, further work should make it possible to harden steels on a production basis without change in cross-section and without heat treatment. Recrystallization of welds by the same process also seems feasible.

briefs . . .

A glossary of optics and spectroscopic terms becomes the fourth in the American Institute of Physics series of science dictionaries. Like the others (Solid State Physics, Acoustics, and Plasma Physics), this one was prepared for a special science writing seminar; but copies are being made available, while supplies last, to PE readers without charge. It's a 30-page printed booklet covering well over 300 terms. Address: Eugene Kone, American Institute of Physics, 335 East 45th St., New York 17.

Zinc could be 3000 times as strong as the best commercially available material, J. M. Sharp of Southwest Research Institute points out, if we knew how to preserve, in massive form, the strength shown by single crystals.

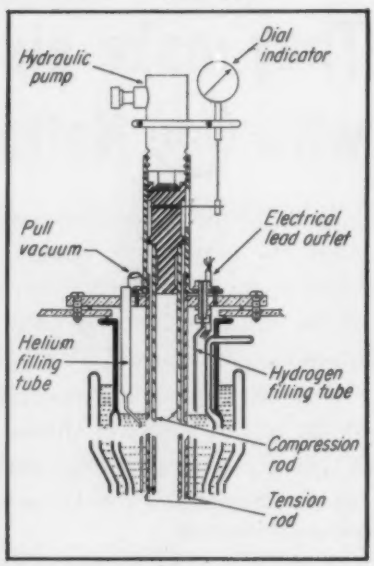
But such high strengths—on the order of 800,000 psi—have been observed only in very fine-diameter "whiskers" where the forces of surface tension are high and imperfections nearly nonexistent. Even in the larger single crystals, strength falls off sharply. Zinc researchers are divided on the question of whether anything like the whisker strength can be achieved on a practical basis; but there is hope that the present 250-psi limit can be lifted. **–ARG**

New pressure-transmission medium: solid hydrogen

To study the effect of hydrostatic pressure on the electrical and magnetic properties of metals, Louisiana State Univ researchers have built an interesting hydraulic device. It's a piston-and-cylinder combination in which solid hydrogen (m.p. is −434.6 F) serves as the pressure-transmitting medium.

Pressures to 5000 atm can be exerted. The diagram shows the basic setup; but, R. J. Deck of LSU warns, piston and cylinder fit are very critical. The system is now being used to study pressure dependence of galvanomagnetic and thermomagnetic effects.

Note: Solid helium has also been used in systems of this type. An article on one such investigation, using solid helium to study pressure effects on superconducting lead, is scheduled for publication in a forthcoming issue of the *Physical Review*. Lead itself has been used in a third system—this one described in *PE*—Jan 9, p 8.



SOLID HYDROGEN transmits pressure, and liquid helium serves as coolant in this system built and now in operation at LSU.

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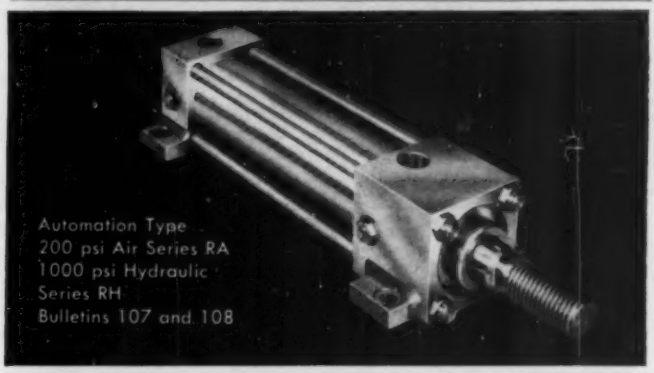

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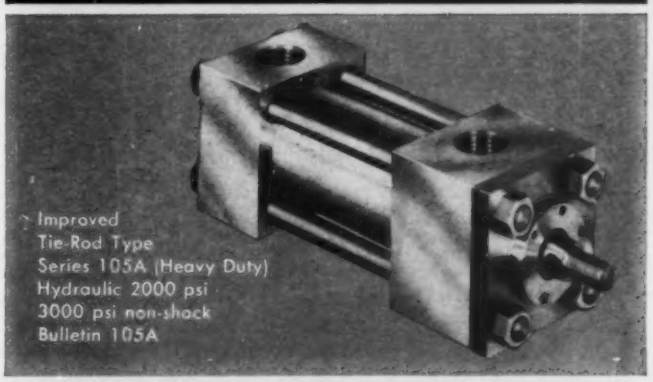

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DEVELOPMENTS TO WATCH...

New metal finishes coming up

A new group of water-miscible alkyds, safer and easier to apply, compatible with both melamine and urea resins, and requiring no metallic driers or freeze-thaw stabilizers, is soon to be introduced by Benson Process Engineering Co. Several types will be available. One features excellent alkali resistance; another, unusual film hardness and mar resistance; a third, flexibility and low cost. Either air-drying or baking formulations can be made. Benson plans to have samples available for evaluation after Apr 1, and technical data sheets are being prepared.

Glass microballoons improve molded plastics

Molded parts that are more rigid, lighter in weight, and less flammable than conventional moldings have been produced at Standard Oil of Ohio's Chemical & Physical Research Labs, using glass microballoons in place of mineral fillers.

In phenolic and polyester laminates, the microballoons produce materials as much as 30% stronger and 20 to 50% lighter than those produced with mineral fillers. PVC plastisols, too, can be strengthened this way. Furthermore, H. E. Alford and F. Veatch of Sohio say that artificial dielectrics can be produced with closely regulated properties over a wide range of dielectric constants by combining the microballoons with metal flakes and a resin binder.

A report detailing properties of the microballoons, and test parts produced with them, is scheduled for presentation to the St Louis meeting of the ACS Div of Organic Coatings & Plastics Chemistry.

New surfacing process claimed by Soviets

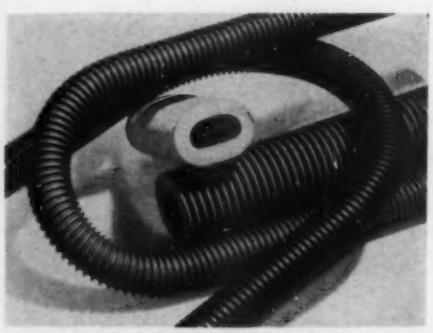
An inert gas-shielded arc system that uses two indirect arcs is claimed to improve quality of metal deposition and reduce required current density. One arc is formed between two unconsumable tungsten electrodes, as in atomic-hydrogen welding; the other between a consumable and an unconsumable electrode.

The thermal effect of the two indirect arcs is considerably greater than that of a single direct arc, Y. L. Krasulin reports in the Soviet journal *Svarochnoye proizvodstvo*; and the electrode burnoff is twice as high as in systems using a conventional consumable electrode.

A transformer with an hf oscillator provides power for the dual-tungsten electrode system; a dc generator for the dissimilar electrodes. The metal transfer can be regulated from drop to spray and vibration of the consumable electrode at sonic frequencies is said to improve wetting action and quality of the deposit.

Gilled tubing for heat exchange

Metal tubing with "gills" shaped into its surface can now be made in mild or stainless steel, zirconium, titanium, aluminum, magnesium, copper, or almost any combination of metals, to provide differential heat-transfer and corrosion-resistance characteristics. Accles & Pollock Ltd of London has produced tubing in sizes from $\frac{5}{8}$ in. at the root of the gill to 6 in. OD, with gills ranging from a maximum height of 0.032 in. for stainless to 0.5 in. for aluminum. Number of gills per inch also varies with the material used (6 for stainless, 8 for aluminum) and minimum pitch ranges from 0.2 in to 0.125 in.



GILLED TUBING can be made in round or oval cross-section and bent to radii "only slightly larger than plain tubing of similar size and heat treatment," its British developers claim.

Semiconductor strain gages being developed

Piezoelectric transducers that produce output signals 25 to 50 times as great as those of conventional wire and foil gages are being developed at Baldwin-Lima-Hamilton. But, its Transducer Dept cautions, these transducers will likely be more expensive than bonded strain gages and somewhat less precise; and there are still problems to be solved in relation to temperature sensitivity and nonlinearity.

Columbium gets high-temperature protection

Coatings that protect columbium from oxidation in air at temperatures at least to 850 F are reported by F. J. Clauss and S. Drake of Lockheed Missiles and Space Div. These are halide-containing oxide films (made, for example, by reaction with hydrogen chloride gas in an oxygen atmosphere at about 900 F); and, the Lockheed men report, the films so formed are considerably more resistant to attack during subsequent heating than are films formed by conventional oxidation processes. Furthermore, they are resistant to flaking and spalling when cooled, and are considerably superior to similar anodic films prepared by oxidation in air or immersion of the metal in alkaline solutions containing halogen salts.

Expendable systems make design headway

Expendable electronic equipment may not be any cheaper than repairable units; but the military agencies are spurring research on it because, they say, expendable modules promise greater reliability, lighter weight and greater speed of repair. Underway now are new studies of optimum size and type, and new tests of tube and transistor assemblies.

Among the studies are investigations of optimum module size at National Bureau of Standards (4 to 8 tubes seems to be the most desirable range), and circuit-assembly reliability tests at several industrial labs.

For the present, at least, microminiature units are not being considered for such applications, the Navy and Air Force say, because these devices can not yet meet reliability standards.

Do-it-yourself conversion gives flow-rate control

A moving shutter and interleaving tongue sections convert a conventional valve into a flow-rate control unit in a new design by Britain's Atomic Energy Authority. The essential elements, which can be inserted into a standard valve body, are a pair of tongued seating and closure sections, a movable shutter, a spindle and a sealing ring.

The seating sections are mounted on the spindle and carry tongues so designed that the ports defined by them as they move together are of the desired shape. The shutter, designed to rotate or move axially, opens and closes the ports and is profiled (rectangularly or logarithmically) to provide the desired flow pattern. A bellows-and-flange system serves as a seal. UKAEA says the union is readily adaptable to automatic control and to mechanical or electrical operation.

The device has been patented, but arrangements have not yet been made for commercial production. Additional information may be obtained from the UKAEA Patents Officer, 11 Charles II St, London, SW1, England.

Rhenium goes commercial in electrical and electronic parts

It's still not cheap but rhenium, one of the newest and most promising of the "Wonder Metals" is beginning to move into commercial products. Latest progress report from the Bureau of Mines notes an increasing demand for the metal for thermocouples (*PE—Oct* 16 '58, p 11) filaments, heaters, and electronic structural components, electrical contacts, and welding-filler materials for tungsten and molybdenum.

Wire and strip are now available in several sizes, but prices remain somewhat astronomical. Base price (for powder) is $680/lb. Strip ranges from $880/lb for 0.08-in.-thick material to $1750 for 0.001 in. Wire can be had in sizes from 0.003 to 0.1 in. The price: 55¢ to $79 a ft.

There is hope for lower costs, though, as the Bureau pushes the search for new sources and new recovery techniques. —ARG

CAMPCO / some practical IDEAS for its use

Plastic Sheet and Film

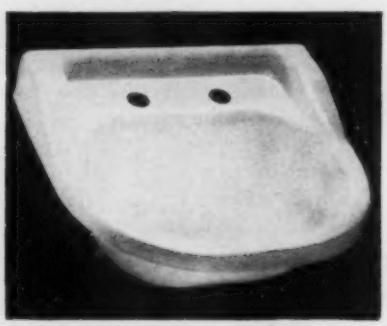
Campco Styrene helps make Jr. Juke kid-proof

This Jr. Juke is a hit with kids and parents alike. That's because the base is formed with Campco S-540 Styrene, an extra high impact strength material, attractive yet durable and tough enough to resist children's rough treatment.

Economical In addition to strength and durability, Campco S-540 has excellent formability characteristics. This proved to be especially important in the deep drawing process used in forming the base. With S-540, complicated curved surfaces and debossed areas can be formed quickly and accurately. Higher production rates and greater economies result.

Special Finish Chanal Plastics Corporation of Rego Park, New York, who vacuum forms the Jr. Juke housing for Shell Electronics of Long Island, specified Campco's "GM" finish. This high-gloss surface, developed and pioneered by Campco, is achieved with a thin coating of compatible glossy material—applied in a manner that it becomes an integral part of the sheet itself. Even in extremely thin forming operations, the brilliant gloss remains unimpaired.

Other Finishes Campco S-540 rubber modified styrene sheet can also be supplied with a mat finish on both sides (MM) and a polished-smooth surface on one side and a mat finish on the other (PM). Available in a full range of colors.



Campco Styrene lightens load in mobile homes

Du Call Miller Plastics Co., of Cicero, Illinois, uses Campco S-540 rubber modified styrene sheet to vacuum form this mobile home sink for C. M. Hoof Co., Evanston, Illinois. Campco's GM high-gloss finish gives the sink a sparkling, china-like appearance, and its nonporous surface assures easy cleaning.

Strong, Light in Weight S-540's high impact strength properties make it possible to achieve dramatic weight reductions in many applications. The sink illustrated, for example, weighs less than one pound, a weight savings of at least 10 lbs. over comparable vitreous types. These high strength and light weight characteristics make Campco S-540 ideal for a wide variety of uses in appliances, toys, and housewares.

Planters formed from Campco Styrene

The Plastics Division of Kusan Incorporated, Nashville, Tennessee, selected Campco extra high impact styrene to form this handsome planter and matching tray, marketed nationally by Ferry Morse Seed Company of Fulton, Ky.

Low Moisture Absorption An important requirement for this application was a material with low moisture absorption properties. Campco Styrene easily met this requirement and offered, in addition, excellent formability and the ability to withstand wear. This same combination of properties has helped make Campco Styrene a popular choice in a wide variety of applications.

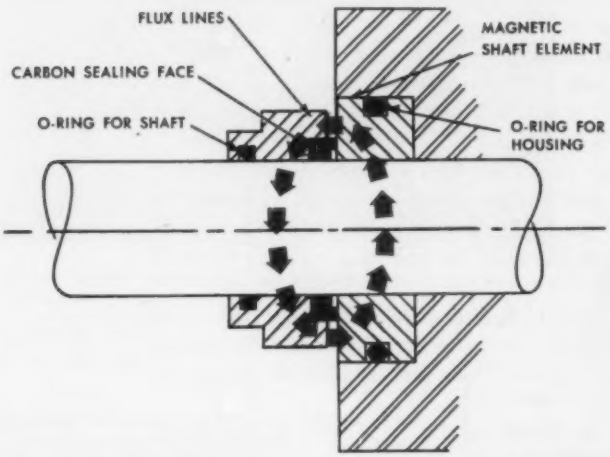
Received Your Campco Personal File? This data-packed reference file on thermo-plastic sheet and film is yours on request—just send name and address on your company letterhead to Campco, 2717-C Normandy Avenue, Chicago 35, Illinois.

CAMPCO Sheet and Film, **a Division of Chicago Molded Products Corp.**

For Positive, Permanent Shaft Sealing . . . Without Springs!

MAGNETIC SHAFT SEALS

New Design Concept Offers Many Distinct Features in High or Low Pressure Fluid Sealing . . .

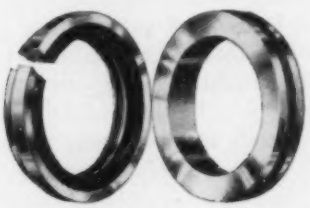


Compactness
Proven Reliability
Economy
Long Life
Versatility
Simple Design
Minimum Friction
Balanced Wear
Easy Assembly
Minimum Maintenance
Interchangeability
For High Temperatures
For All Shaft Sizes

UNIQUE PRINCIPLE

Magnetics have revolutionized seal design. Magnetic force and fluid pressure replace spring action in this completely new line of rotary seals. A magnetized ring of Alnico V, press-fitted into equipment house, firmly holds the mating ring on the shaft element by magnetic force. The carbon ring in the face of the shaft element, in balanced contact with the lapped surface of the magnet, forms a permanent, self-adjusting face seal. O-rings in both shaft and magnetic elements prevent leakage of confined fluid or gas.

Design advantages . . . no springs or screws required . . . more compact, lighter seals . . . self-positioning when assembling . . . even distribution of sealing force . . . no initial face leakage . . . slow, even wear-in period lasts life of seal . . . self-lubricating carbon sealing face runs cool, minimizes wear.



MANY APPLICATIONS

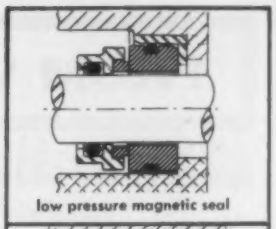
Exceptionally suited to aircraft and missile applications, magnetic seals provide design engineers throughout industry with a totally new approach to their sealing problems. Magnetic seals have provided reliable service under severe operating conditions against a wide variety of fluids. Standard seals effective up to 3000 psi, temperatures to 500°F. . . . special adaptations to suit extreme temperatures, pressures or high rubbing speeds.

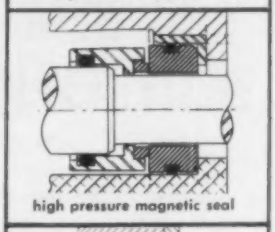
MANY DESIGNS AND ADAPTATIONS

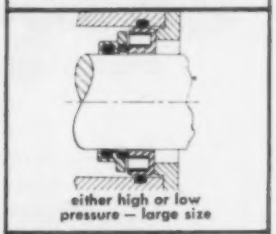
The seals illustrated here show the versatility of the magnetic principle. Many other basic designs and adaptations are available. Magnetic Seal Corporation's engineers will gladly make recommendations on your particular requirements.

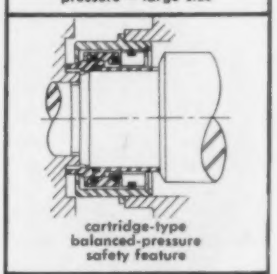
REQUEST LITERATURE

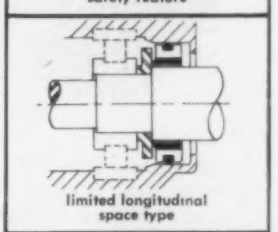
For additional technical information, request complete brochure.

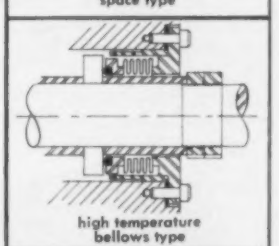

low pressure magnetic seal

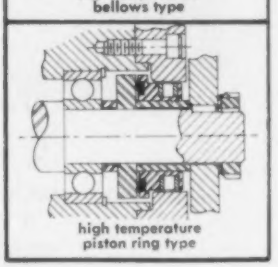

high pressure magnetic seal


either high or low pressure — large size


cartridge-type balanced-pressure safety feature


limited longitudinal space type


high temperature bellows type


high temperature piston ring type

magnetic seal corp.

166 Bay Spring Ave.
West Barrington, R. I.

FROM WASHINGTON . . .

Spending for limited warfare to increase

Defense contractors are gearing up for what seems certain to be a wave of spending for limited-war weaponry. The Kennedy Administration has already made it clear that the military emphasis over the past several years has swung too far in the direction of missile and big-bomber spending.

Now, plans are to beef up the limited-war capability of the nation. It is expected to add from $1.5 billion to $2 billion to Pres Eisenhower's $42-billion appropriation request for fiscal 1962. Asst Defense Secy Paul H. Nitze reportedly pegs the requirements at $2 billion to $3 billion annually over the next couple of years.

The Army will obviously get the bulk of the limited-war money. Right now plans call for the Army to get some $1.8 billion for procurement of conventional arms and equipment; the Marine Corps is slated for $159 million.

Army's money will go for such items as a new 105-mm self-propelled howitzer, 175-mm guns, 80-mm recoilless rifles, and 81-mm mobile supported mortars. The Army also wants to buy quantities of the M-113 armored personnel carrier, M-60 tanks, the Davy Crockett bazooka-type launcher for low-yield nuclear warheads and the like.

Production contracts won't necessarily go to R & D developers of the new equipment. But, Army sources concede that the company that does the development work on a piece of equipment stands a better than even chance of getting the production contract.

Competitive bidding, however, will be closely watched. It is part of the over-all move to beat down the high costs of military procurement.

Another move to shelve the B-70

Watch for a reshuffling of some of the big military programs. Reportedly, the Air Force is thinking of cutting back the B-70 program again. The plan, if carried out, would limit the program to building a prototype of the Mach 3 aircraft and cancel work on electronic-contract subsystems.

Another rumored cut would cancel the last two Titan II squadrons. Of the 14 Titan squadrons authorized so far, 8 are the advanced Titan II series. However, no firm decisions have been made on the measure as yet.

Navy is reported to be opposing a move to shelve its plan to arm the nuclear-powered cruiser, Long Beach, with Polaris missiles. It will be some weeks before final decisions are made. But, the trend is toward a reshuffling of some of the big all-out war projects in favor of adding more strength to the conventional limited-war capability.

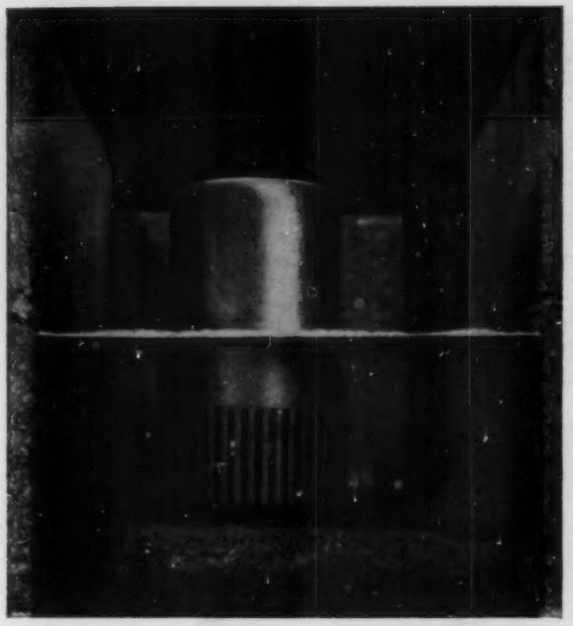
Industry favors A-powered rockets

Industry has told Congress that nuclear-powered rockets hold the key to long-range space exploration. And, as such, officials from companies like Rocketdyne Div of North American Aviation Inc, Lockheed, Aerojet General, Convair, etc, want a higher priority placed on nuclear rocket research and development programs.

The immediate program up for inspection before the House of Representatives' Space and Astronautics Committee was Project Rover. But, before the 2-week-long hearings adjourned, industry officials called for expanded research into follow-up nuclear rocket programs.

A key factor in the future of rockets rests in more research into materials. But safety follows as a close second. Nuclear rockets are being considered seriously by the military for space use as well.

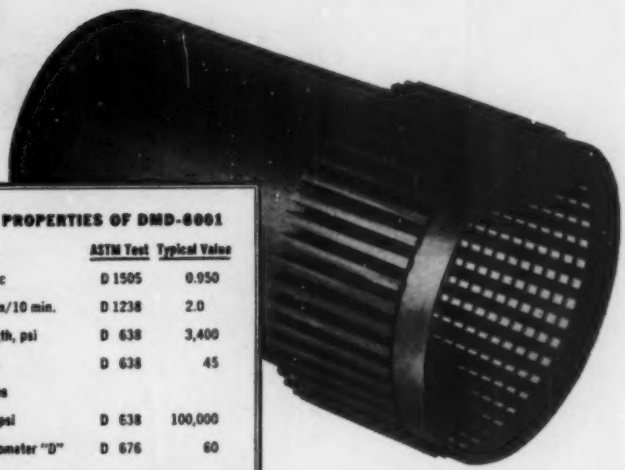
Detailed study to define nuclear-rocket-engine characteristics over a wide thrust range has been started by the Air Force. Potentially, nuclear rockets can produce two and three times the thrust of ones with chemical fuels, the military says.



END CORROSION DAMAGE ...DESIGN WITH HIGH-DENSITY POLYETHYLENE

BAKELITE BRAND high-density polyethylene gives 100% corrosion resistance with strength and molding ease

Strong Plastic Housing for Sump Pump—Fostoria Corporation's "Dynasumps," designed for rigorous underwater service, are housed in covers molded from BAKELITE Brand high-density polyethylene DMD-6001. The cover-strainers are deep-drawn molded in one piece by Haas Corporation.

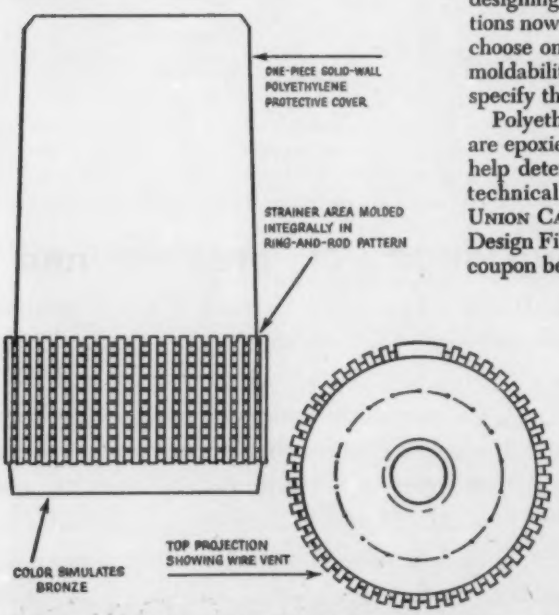


Nothing to Corrode in This Cover—One-piece molding provides neat, tight-fitting cover with no screws, bolts, or nuts to vibrate, work loose or corrode. Drainage water and chemical detergents have no adverse effect on this completely corrosion-resistant component.

TYPICAL PROPERTIES OF DMD-6001

Properties	ASTM Test	Typical Value
Density, gm/cc	D 1505	0.950
Melt index, gm/10 min.	D 1238	2.0
Tensile Strength, psi	D 638	3,400
Elongation, %	D 638	45
Secant Modulus (Stiffness), psi	D 638	100,000
Hardness, Durometer "D"	D 676	60

Easy to Mold, Tough in Service—Toughness and rigidity are characteristics of parts molded from BAKELITE Brand high-density polyethylene. Molding ease and flexibility go far in eliminating many common production problems. Result: a durable, smooth-functioning part that is resistant to water and most common chemicals.


ONE-PIECE SOLID-WALL POLYETHYLENE PROTECTIVE COVER
STRAINER AREA MOLDED INTEGRALLY IN RING-AND-ROD PATTERN
COLOR SIMULATES BRONZE
TOP PROJECTION SHOWING WIRE VENT

Finding the right combination of properties needed in the product you're designing is made easier by the variety of BAKELITE polyethylene formulations now available. In addition to low, medium and high densities, you can choose one of the new polyethylene copolymers. Stress-cracking resistance, moldability, dimensional stability, toughness, flex life, rigidity—you can now specify the properties you require.

Polyethylenes are only one group of BAKELITE Brand plastics—the others are epoxies, phenolics, styrenes, and vinyls—from which you may select. To help determine the one you could use to your best advantage, call on the technical experience and know-how of UNION CARBIDE. Consult Sweet's Product Design File, section 2a/ui. Or just mail the coupon below.

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Please send me information about BAKELITE Brand Plastics for Design, with emphasis on these properties:

The type of application being considered is:

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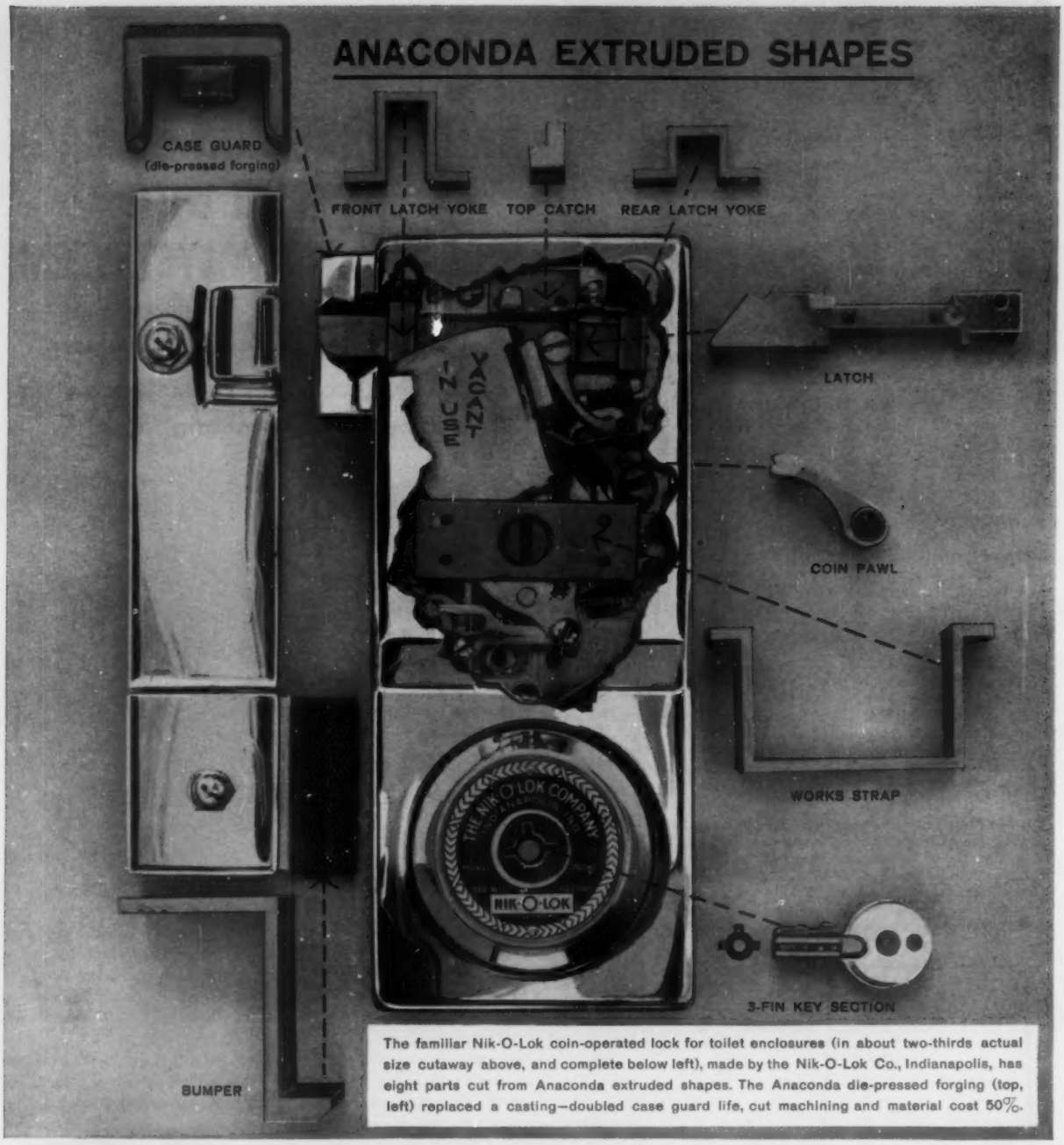
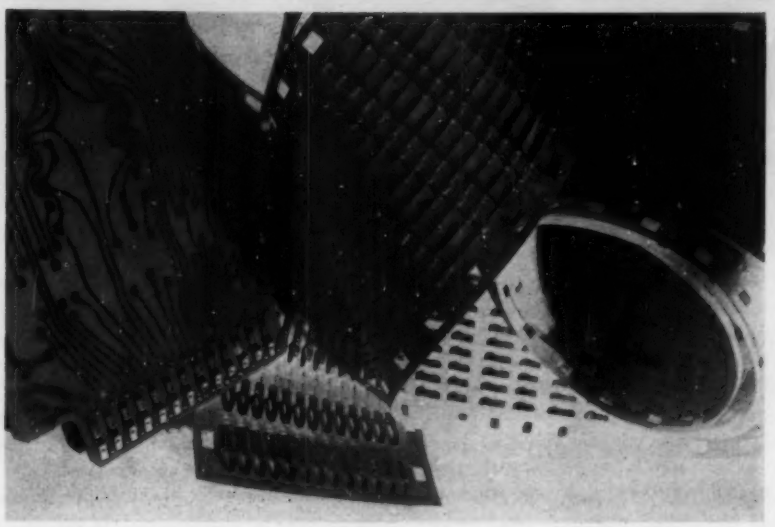


The familiar Nik-O-Lok coin-operated lock for toilet enclosures (in about two-thirds actual size cutaway above, and complete below left), made by the Nik-O-Lok Co., Indianapolis, has eight parts cut from Anaconda extruded shapes. The Anaconda die-pressed forging (top, left) replaced a casting—doubled case guard life, cut machining and material cost 50%.

How parts sliced from long lengths of "premachined" brass shapes cut costs. It starts in design. You select cross sections which minimize subsequent machining—and scrap. The only limitation is that grooves, slots, etc., must parallel the axis of the extruded bar. The smooth surface of extruded shapes reduces many finishing operations. And high dimensional accuracy simplifies assembly. In addition, you get superior, long-wearing parts that improve the quality of your product, because of the strong, homogeneous wrought-metal structure of extruded shapes. For imaginative and practical help in adapting extruded shapes to the economical production of intricate parts, see your Anaconda representative. Or write: Anaconda American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

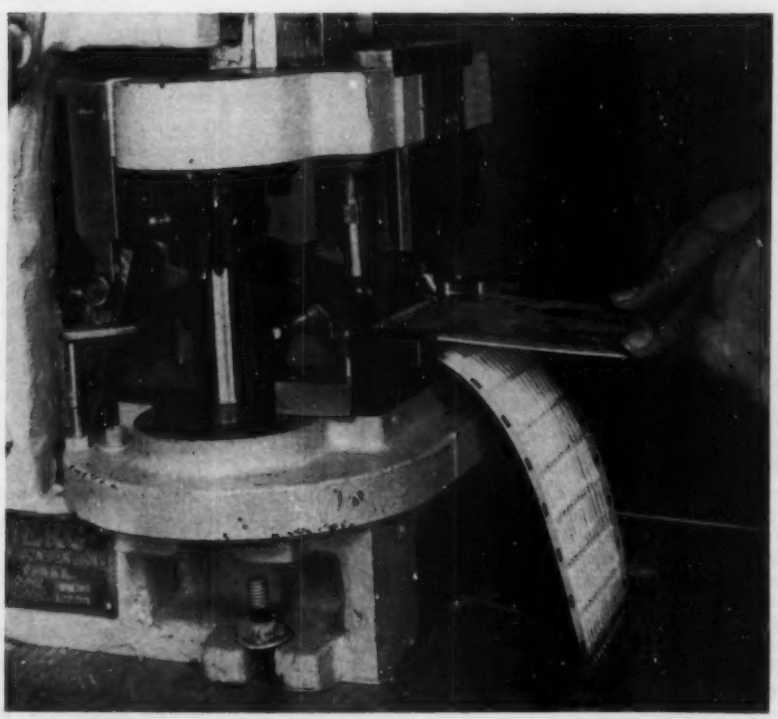
6143 **ANACONDA®**

THE ENGINEERING WEEK



By the Roll—Programed Clips Staked to Printed Circuit Boards

Paper roll, gold-plated clips and a printed circuit board (top)—these three work together in a system that permits uniform and tight staking at high speed of electrical-connector clips to printed circuit boards. Berg Manufacturing Co, New Cumberland, Penna, developed the method and machinery to do the job. Clips are fed from Syntron hoppers down two feed tracks (see our cover photo) and programed onto a paper tape—first a row of short clips, then a row of long clips. The clip-carrying roll is then wound on a reel and shipped to customer for insertion on etched boards. Berg assembly machines feed paper roll through the machine and printed circuit board is hand-fed and turned to take both sizes of clips (photo below). This method processes 600 boards an hour against 30 per hour by hand method. In addition, hoppers in customer plant are not needed—resulting in lowered maintenance costs—and cost of material is less, too, because strip terminals are not used.



Detroit Compacts—but Volkswagen Enlarges

BONN, GERMANY—Is Volkswagen feeling the pinch of lagging auto sales both here and abroad? Or are the German people just leery of buying stocks in automobile companies? Whatever the reason, VW Wolfsburg Works took the unusual course of releasing to the press details and pictures (page 16) of the much-heralded new and larger Volkswagen. First public viewing is scheduled in seven months at the biannual German automobile show in Frankfurt.

Though the details released are scanty, it is obvious that there will be no departure from the well-tried mechanical layout of a flat, opposed-piston, rear-mounted aircooled engine with integral transmission and rear-axle assembly. Engine is said to be rated at 54 hp (SAE) to give a top speed of about 80 mph. This is a 1500-cc engine as opposed to present 1200-cc units used in the smaller car.

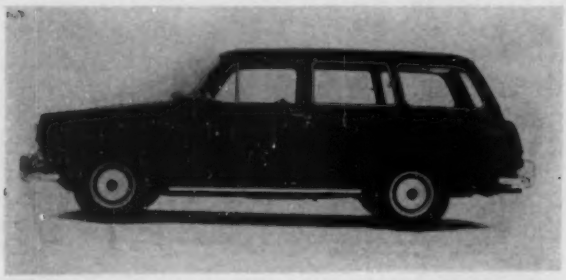
WORLD-WIDE APPROACH

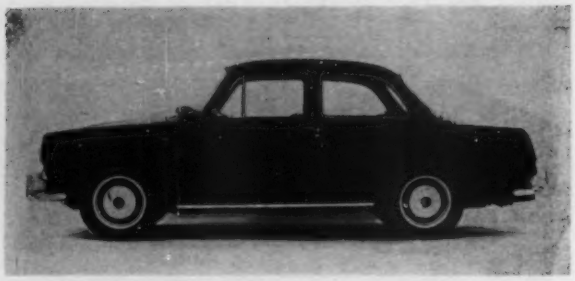
The new body style closely follows current trends in international design. A large luggage compartment is provided under the front hood, and a roomy external access boot is available at the rear. Volkswagen emphasizes that the engine is housed separately from the luggage boot, is readily accessible, and provision has been made for rapid removal and replacement.

Two models will be made available initially, a two-door sedan and a station wagon. Price is believed to be about $1500.

Some think here that the recent Borgward crisis—ouster of its president, and company reorganization—coupled with falling quotations for both Daimler-Benz and NSU (blue chip) shares has discouraged would-be buyers of VW stock. The company hopes that by releasing details of the new model now it can pep up sales to small investors before the March 15 deadline. After this date, unsold stock will be offered to other stock market operators and some shares might even find their way to the Wall Street market.

Up to now, Volkswagen has not





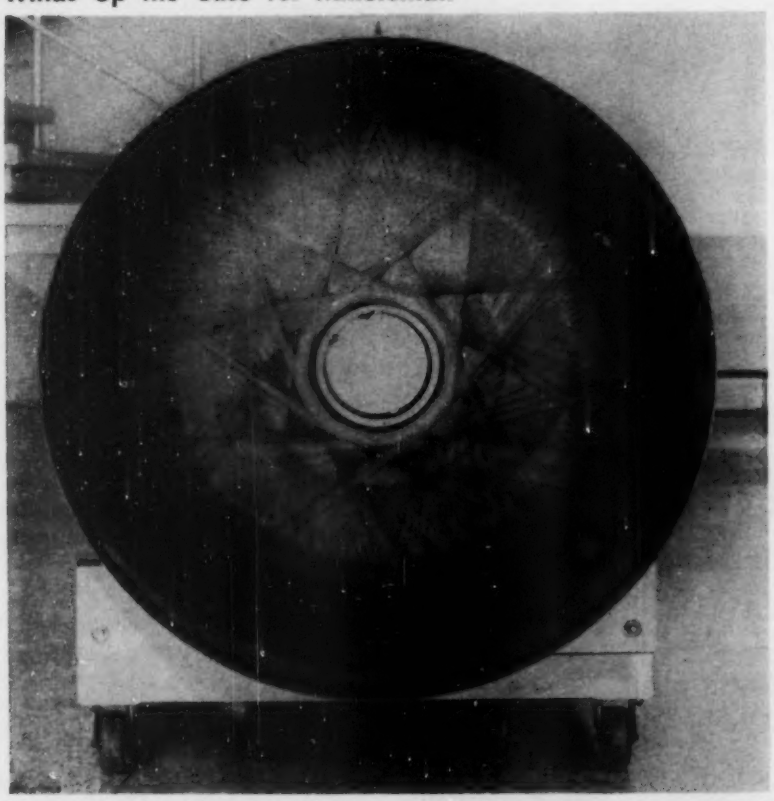
VOLKSWAGEN has designed these "big brothers" for the European market; they will not be sold in the US. These new VW-1500s will be offered in the two-door sedan and station wagon.

been seriously affected by the weakening European car market. Through 1960, annual production was upped from 750,000 to 900,000 and by the end of 1961 it is confidently expected to reach the 1-million-unit mark. This is about the limit of production capacity. However, the uncertainty of the situation, even to mighty Volkswagen, is reflected in current delivery schedules—about 2 years ago, delivery took about 24 months; now this has been pared to 6 weeks or less with the gap rapidly closing.

The new more-powerful deluxe model introduced last year set delivery back a step but there is reason to believe that the order backlog will be cleared during 1961. By bringing in the new 1500-cc model now, VW hopes to keep supply and demand in balance, and to maintain a steady flow of production.

—James Morrison, Bonn News Bureau

Winds Up the Case for Minuteman



The case for this third-stage Minuteman rocket (shown here without its final coatings) contains 188,604 miles of continuous glass filaments wound in a pattern. Called Spiralloy by its builder, Hercules Powder Co, Rocky Hill, NJ, the plastic-glass case material is lighter than aluminum, is as strong as moderately heat-treated steel, and said to be serviceable at temperatures of outer space. The rocket motor encased by Spiralloy is also built by Hercules and incorporates these features: a solid propellant with the highest specific impulse of any measured to date, pivot nozzles used for thrust vectoring, thrust termination which permits range control and accurate programing, and lightweight nozzles made of non-eroding materials. These factors plus the light case structure will permit larger payloads over greater distances.

NSPE Sees Same Goal For All Engineers

WASHINGTON—Officials of the 54,000-member National Society of Professional Engineers are pressing Congress to approve legislation which they believe will benefit associations of professional engineers.

Under scrutiny is language of the Taft-Hartley Act which, according to NSPE "is so broad and generalized in defining a labor organization that engineering 'sounding boards' could be classified as labor unions."

NSPE itself defines a sounding board as a nonbargaining association of engineers, including members of management, employed by one industrial concern whose purpose it is to improve communication between professional engineers and management by serving as an objective fact-finding body, and whose activities are carried out in accordance with the professional concepts of NSPE.

And because these boards include members in supervisory as well as nonsupervisory capacities, they're liable to attack as company-dominated, labor organizations, NSPE says.

Corrective legislation incorporated in the Kearns' Bill (HR 412) would permit all level of engineers in a company to discuss matters of a professional nature through such a board.

NSPE holds that all members of the engineering profession, regardless of position or job assignment, have common interests and goals. ■

Mechanical and Personnel Problems Plague Automatic Post Office

WASHINGTON—Efforts to streamline the nation's postal system have run into a storm of criticism, a congressional investigation and more than a few political repercussions. Center of the storm is the highly mechanized postal center at Providence, RI. Known as Project Turnkey, (*PE—Jan 11, '60 p 16*), the 126,000-sq ft facility was built and equipped by Intelex Systems Inc, a subsidiary of International Telephone and Telegraph Corp.

The snag in the program is that the supermodern postal facility is not performing the mail handling miracles it was billed to achieve. In fact, it has been labeled by Rep J. Vaughan Gary (D-Va), chairman of the House Treasury-Post Office Subcommittee, "as having failed miserably to meet expectations." And the congressional committee has launched an investigation into the matter.

ITT says, "We are astounded by the inaccuracies of the statement about Project Turnkey made by Rep. Gary. Turnkey was designed to serve as a postal laboratory and is capable right now of fulfilling that function should experimental equipment be supplied by the Post Office Department for test." ITT further states that "as the project developed from a research and engineering standpoint, all facts and figures pertinent to the development were given to the appropriate committees of Congress." Furthermore, "committee members were invited to Providence by the previous POD administration," and "to our knowledge, none of them availed themselves of the opportunity."

Postmaster General J. Edward Day sums up the matter with "It doesn't work." And Day lays a heavy portion of the blame on his predecessor, Arthur Summerfield, for ballyhooing the performance of the center far out of proportion to its actual capabilities. Day, however, has made about as many headlines in knocking down the project as Summerfield did in building it up.

Sitting in the middle is ITT who points out that "to our knowledge, no one ever said that Turnkey would be 'fully automatic.' However, it is automated."

There is little question but that the postal center is having trouble getting into operation. But, even the Post Office Department says the trouble lies about 65% with personnel and about 35% with equipment. Turnkey is equipped with machinery that has proved itself in day-to-day use in Israel, Belgium, West Germany, and at the main post office in Washington, DC, ITT points out, but this is the first time anywhere that this equipment has been tied together in one system.

TWO PROBLEM AREAS

Equipment problems have developed in two areas of the mechanized mail-handling operation. One is with the culling machines that separate normal-size letter and postal cards that can be further processed automatically from packages and odd-size mail.

Raw mail as collected from street drops is channeled via conveyor belts to the culling machines, where standard-size mail theoretically drops through slots and is further conveyored for automatic processing. The problem, however, is that much of the regular-size mail rides through on top of the odd-size mail and is not properly culled. It has forced the center to perform a preculling operation on the raw mail before it is sent to the cullers. Engineers from both ITT and Post Office are trying to figure out ways to correct the culling problem.

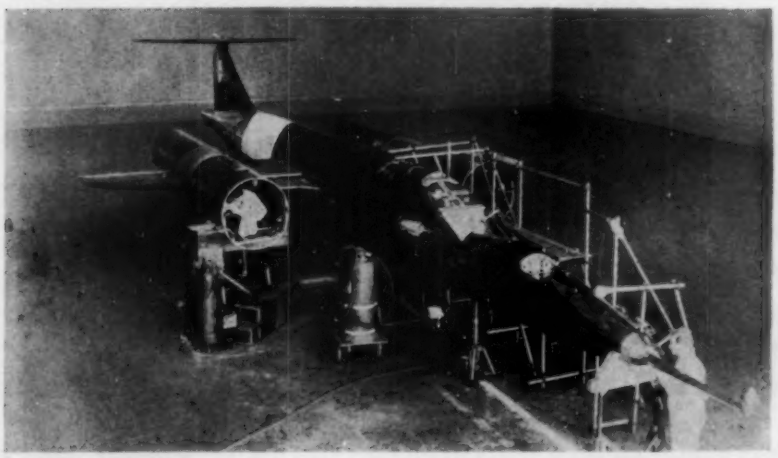
The other major mechanical problem is with the automatic facer-canceling equipment. Letters coming to this unit from the culling machine are supposed to be automatically cancelled across the stamp. It is designed to reject certain pieces such as metered mail. But, in practice, the Post Office finds that the equipment also rejects window envelope mail and postal cards. This amounts to about 30% of all mail fed into the machine.

The fault here, the Department says, is not a matter of adjustment but rather inherent in the design. Working on a light-sensing principle, for example, window envelopes reflect enough light to cause the machine to reject the mail for cancellation.

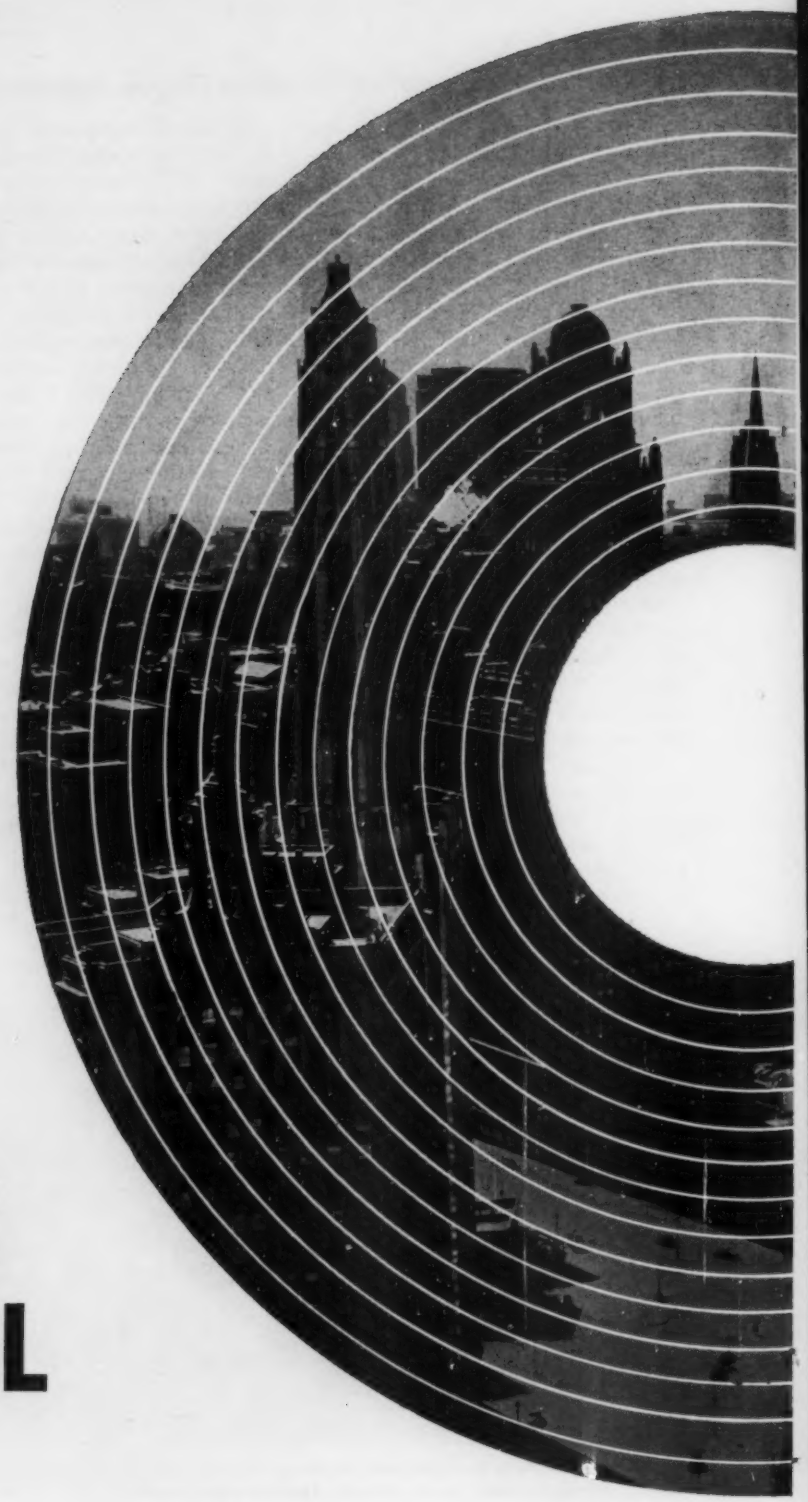
Beyond these two mechanical problems, the bulk of the troubles are minor or rest with the personnel op-

continued on page 20

Stainless Steel Finds Speed-record Customer



The Bristol T-188 is a single-seat, midwing monoplane with twin-nacelle powerplant, and is intended to be world's fastest atmosphere-aircraft (1500 mph). According to Bristol Aircraft engineers, the T-188 utilizes more stainless steel than any aircraft to date. Its keel boom is forged and machined from a single piece of stainless type-403 rolled barstock, 39 ft long. Original cross-section of 4 by 3¼ in. was reduced to flanged thicknesses varying from 0.1 to 0.45 in. Final length measured slightly less than 27 ft. The T-188's twin-nacelle powerplant is said to be world's largest aircraft stainless forging; its cylindrical assembly consists of three stainless type-403 forgings (each weighing up to 8000 lb as-forged). Reforging and machining reduced weight to about 80 lb each—171 to 270 lb for the three forgings as installed. Solid type-403 stainless rivets perform efficiently in a fully hardened and tempered condition at 75 to 80 tons per sq in.



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CIRCLE 19 ON READER SERVICE CARD

continued from page 17

erating equipment. In some cases, however, the Department says the expected performance may have been set too high when the system was designed. For example, the mail is sorted to 300 different destinations by a person operating a console keyboard. The operator reads the destination of letters, then pushes a key to channel the letter to the right destination slot. As designed, each operator of some six consoles is supposed to handle some 50 letters a minute. At present, working time is 45 min. on the console with a 15-min. break for an 8-hour shift. But the Post Office says there is considerable doubt that an operator can effectively work to such a schedule.

To this, ITT says "where manual handling exists it is by design and not by accident." But, "since Turnkey became fully operative, not one word of serious criticism of its operation has been reported to us by the Post Office Department people who have visited Turnkey on a regular basis to check its performance."

Actually, many of the problems now plaguing the Turnkey operation are blamed on the rush with which the facility was put into operation. Construction was started in April, 1959; it was dedicated on Oct 20, 1960. But it was a good month before any postal employes could move into the facility. And it was mid-December before the Post Office had most of its employees in the center.

Then the Department was faced with a decision either to hire extra space for the Christmas mail rush or start using the new facility. The impact of the large volume of Christmas mail during the shakedown operation of the equipment was somewhat disastrous, one Post Office spokesman now admits.

Thus, the new center has, in effect, had only about 60 days to iron out the bugs in equipment and management. But, even this period has been disrupted by a change in Administration and a congressional investigation.

ITT points out that "when two recent snowstorms shut down virtually all postal service in New England, Turnkey continued to operate and handled mail of all types that was rerouted from the affected areas." It goes on to say that "Wade Plummer, former director, Office of Research and Engineering for the Post Office Department, has informed us: 'Turnkey is operating far ahead of expectations. It was the intention of the previous Post Office Department administration to phase in mail from the surrounding areas on a planned basis to utilize the full capacity of the facility. I am certain Turnkey can do the job.'"

Right now, the Department has three teams of experts at the facility to determine just what is wrong and right with the operation. These include a team of engineers, in which are two from the National Bureau of Standards, to assess equipment performance; a team to determine manning requirements; and one to check on mail-damage reports. It will be another few weeks before they report back to the department in Washington with their findings of the Turnkey operation.

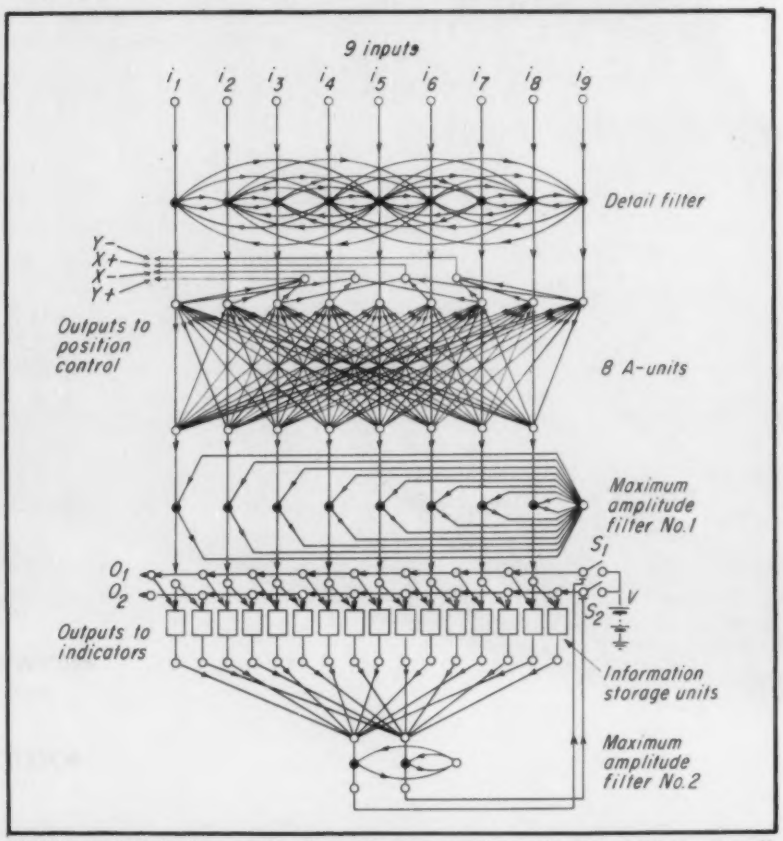
In the meantime, the Chicago post office is reporting trouble with its Mail Flo system. This is not as elaborate as Turnkey, but mail damage has been reported, as well as some equipment trouble.

–Seth Payne, Regional Editor

British Learning Machine Will Simulate Brain

LONDON—An automatic pattern recognizer (APR), similar in principle to the neural circuits of the human brain, is expected to springboard an investigation of the brain's learning processes when it is completed next year.

Unlike other APR devices such as the US' Perceptron (*PE—July 4 '60, p 17*), this computer will process signals in analog form clear through to the output indicating stages. According to APR's inventor, Dr W. K. Taylor of University College here, two advantages result from this ability to maintain signals in analog form with-



SIGNAL FLOW of an automatic pattern recognizer. Second maximum amplitude filter insures that only the largest sum of 8 information storage unit outputs reaches the final output stage. Storage is achieved by 4000 motor-driven potentiometers which record the strength and duration of the maximum amplitude filter outputs produced by the same pattern.

out processing: (1) the design problem of classifying the binary-input patterns inherent in digital techniques is avoided; and (2) there is no preset threshold value for triggering an evaluator circuit — therefore, noise and changes in lighting intensity and contrast do not affect the circuit.

Preliminary tests with a small unit having a 9-cell "eye" and 16 storage units have been encouraging. A typewritten "T" was recognized with 100% accuracy after only two viewings with a superimposed teaching signal, while small vertical shifts and different typefaces did not upset identification.

The large APR will identify patterns and sort them into an initial 100 different classes. Signals are received from a 1-ft-sq sensing matrix of 100 photomultipliers which can sense up to 10 intensity levels; they are then passed through 4000 potentiometers or A-units which can give the algebraic sum of the multiple, continuously variable inputs and pass on proportional outputs. These A-units are interconnected to the sensing matrix in a mutually exclusive manner so that for any given pattern, each A-unit will have a unique output level.

REPETITION MINIMIZED

A comprehensive set of summing networks for the 100-cell matrix would require (2^{100}-1) A-units. To reduce this to a practical quantity, human pattern-recognition methods have been studied and by applying human analogies, it's been possible to discard many of the units that produce redundant information.

The central region of the human retina (the fovea) affords more acute vision than the outer areas; so, in the APR, field resolution is graded down from the center of the sensing matrix. The further from the center of the matrix each photomultiplier is placed, the larger the area it views. Servo-centering, triggered by pattern intensity on the x and y coordinates, will focus the high-resolution portion onto small, off-center patterns—on a par with human eye movements during reading.

Another means of cutting down on A-units is detail filtering, which relates to the fact that some cells in the human retina respond only to corners and edges, not to plain surfaces. In the APR, filters positioned in front of the A-units emphasize signals from edges and corners in the pattern. Actually, filters are summing amplifiers with the output of each amplifier fed back to the inputs of all the others, so that signals which give the most detail are emphasized. The technique is akin to "edging" of binary patterns but Dr Taylor says detail filtering is up to a billion times faster.

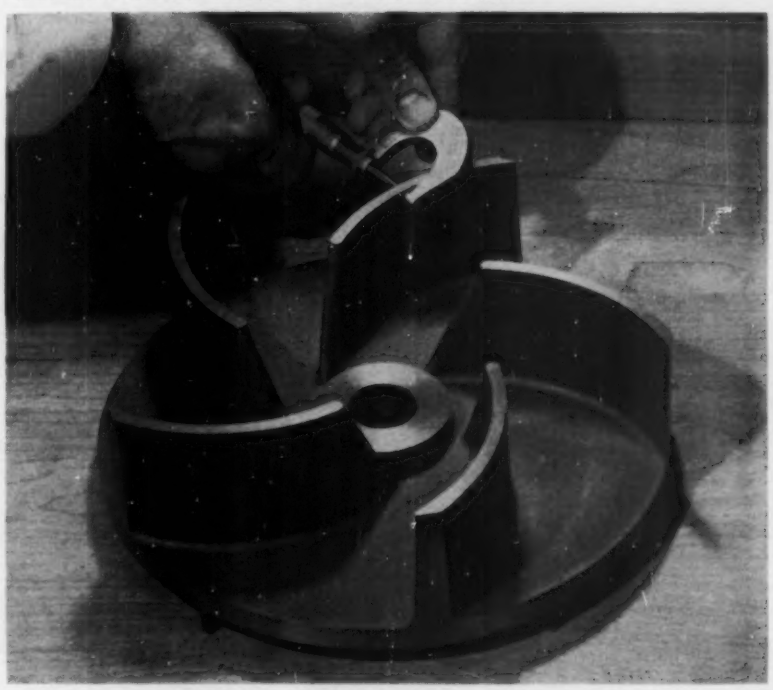
Information is stored by 4000 motor-driven potentiometers which record the strength and duration of the maximum-amplitude filter outputs produced by the same patterns. At the same time, they increase the gain of the paths between the filter outputs and the inputs to the final output stages according to classification signals accompanying the pattern. These classification signals may be keyed-in manually or automatically (drawing at left, below).

Initially, potentiometers are positioned at random so that viewing any one pattern will increase the transmission of one path by altering potentiometer position. Teaching signals increase the circuit gain and enable different patterns to be classified on the same output. As a result, the same letter in different typefaces will be correctly identified. If desired, different letters can be classified as the same. APR may even be able to recognize human faces by imposing different teaching signals for different faces but the same signal for different aspects of the same face.

Dr Taylor is most interested to learn how near the apparatus duplicates the visual system of the human brain—the A-units and information-storage units serving as functional analogs of the neurons and synapses of the brain. As well as determining optimum networks, the onset of nervous breakdown will be stimulated by giving too high a gain to one circuit which will overload memory and cause disruption of recognition.

—Nick Landon, London Bureau

Reusable Molds Make Titanium Practical



A 9-in.-dia impeller is said to be the first titanium casting produced by way of a new permanent-mold casting technique. Called Impel Casting, the new method produces approximately 100 parts per mold. Previously titanium has been cast in graphite molds with production of parts often limited to one part per die. This made the price of titanium castings impractical, despite the metal's high corrosion resistance. Impel Casting relies on the high fluidity of titanium to produce high strength, accurate, intricate and stable parts. The process calls for a titanium electrode, with molten titanium "impelled" into the die cavity. Method developed by Titanium Metals Corp of America, NY.

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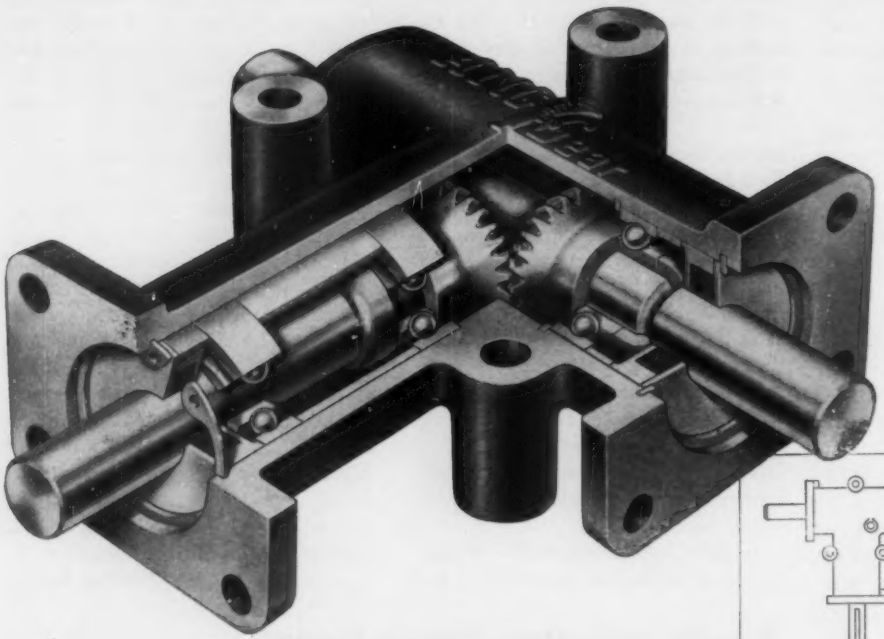
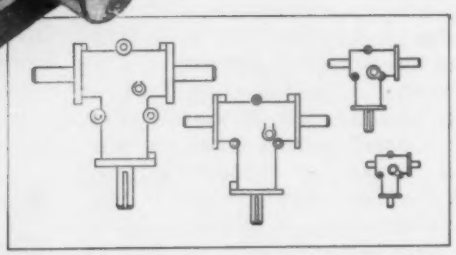


Quality of ANGLgear construction is evident in cutaway view. ANGLgear gives you all the features of other drives, plus greater hp range (⅛ to 5); permanent lubrication; and Coniflex* design gears for more even load distribution, reduced wear, quieter operation.



ANGLgear is available from local distributor stocks in 4 sizes, 16 models, with various gearing and shaft options.

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Besides being maintenance-free, ANGLgear is also easy to design into your power transmission systems because of its universal mounting feature. And it invariably costs less than other types of drives. ANGLgear is distributed nationally and is available immediately from local distributor stocks in the models listed here. Special sizes, special gear ratios, etc., can also be furnished. For complete engineering data, contact our local distributor, or write direct for new Catalog IA-58. *ANGLgear design template kits are available on request.*

*Trademark of the Gleason Works

BASIC MODEL DATA

Model	Type	Gear Ratio	HP	RPM Output Shaft	Ultimate Static Torque lb. in. Output Shaft	Shaft Dia.	Wt., lb.
R-300	2-way	1:1	1/3	1800	250	3/8	.5
R-300-2	2-way	2:1	1/5	1800	250	3/8	.5
R-310	3-way	1:1	1/3	1800	250	3/8	.5
R-310-2	3-way	2:1	1/5	1800	250	3/8	.5
R-320	2-way	1:1	1	1800	1000	5/8	2.2
R-320-2	2-way	2:1	3/5	1800	1000	5/8	2.2
R-330	3-way	1:1	1	1800	1000	5/8	2.4
R-330-2	3-way	2:1	3/5	1800	1000	5/8	2.4
R-333	2-way	1:1	2-1/4	1200	1500	3/4	8.7
R-333-2	2-way	2:1	2-1/4	1200	1500	3/4	8.7
R-335	3-way	1:1	2-1/4	1200	1500	3/4	9.0
R-335-2	3-way	2:1	2-1/4	1200	1500	3/4	9.0
R-340	2-way	1:1	5	1200	2500	1	14.5
R-340-2	2-way	2:1	5	1200	2500	1	14.5
R-350	3-way	1:1	5	1200	2500	1	15
R-350-2	3-way	2:1	5	1200	2500	1	15

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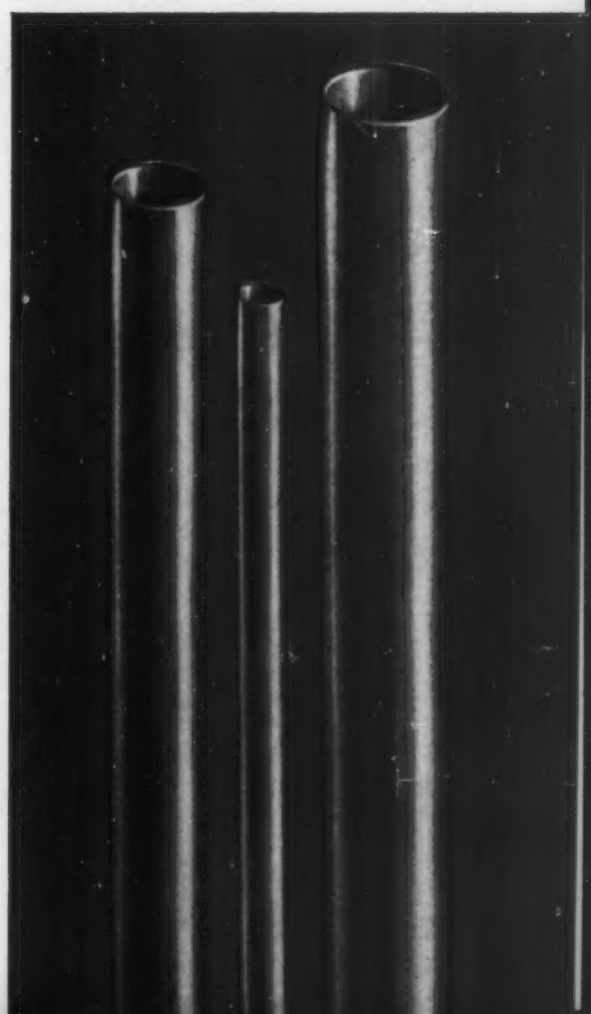
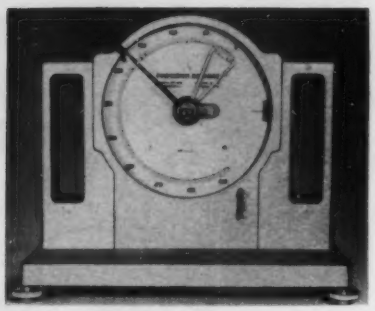
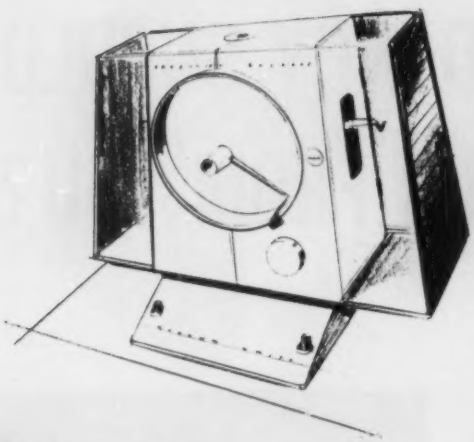
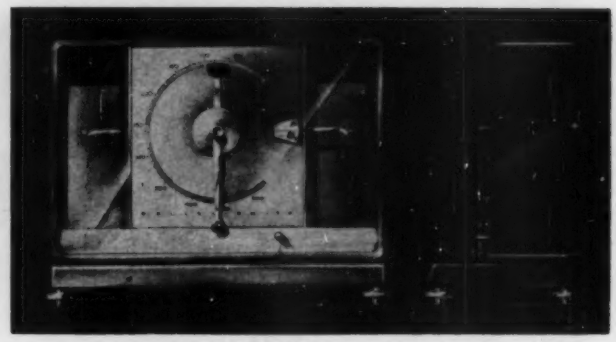


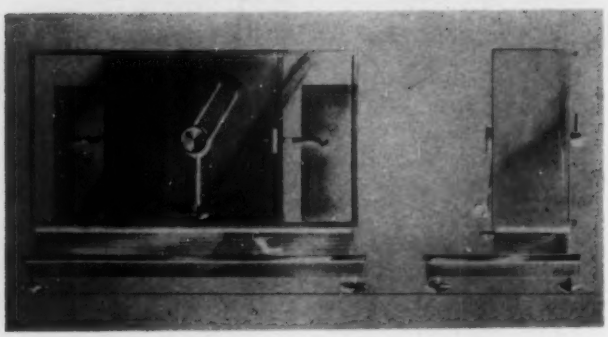
TRENDS IN INDUSTRIAL DESIGN

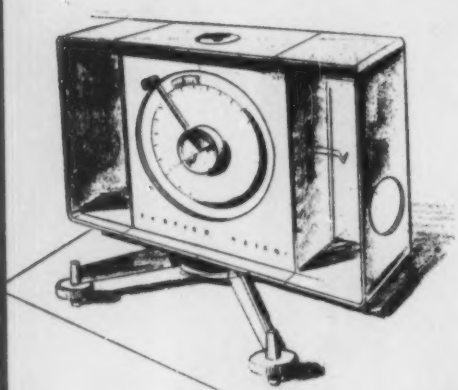


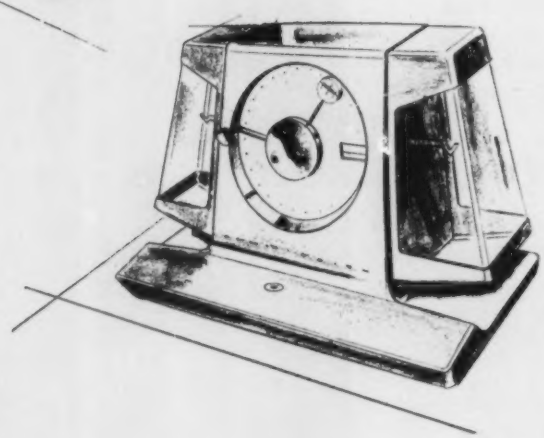
REDESIGNING A HALF CENTURY OF SUCCESS



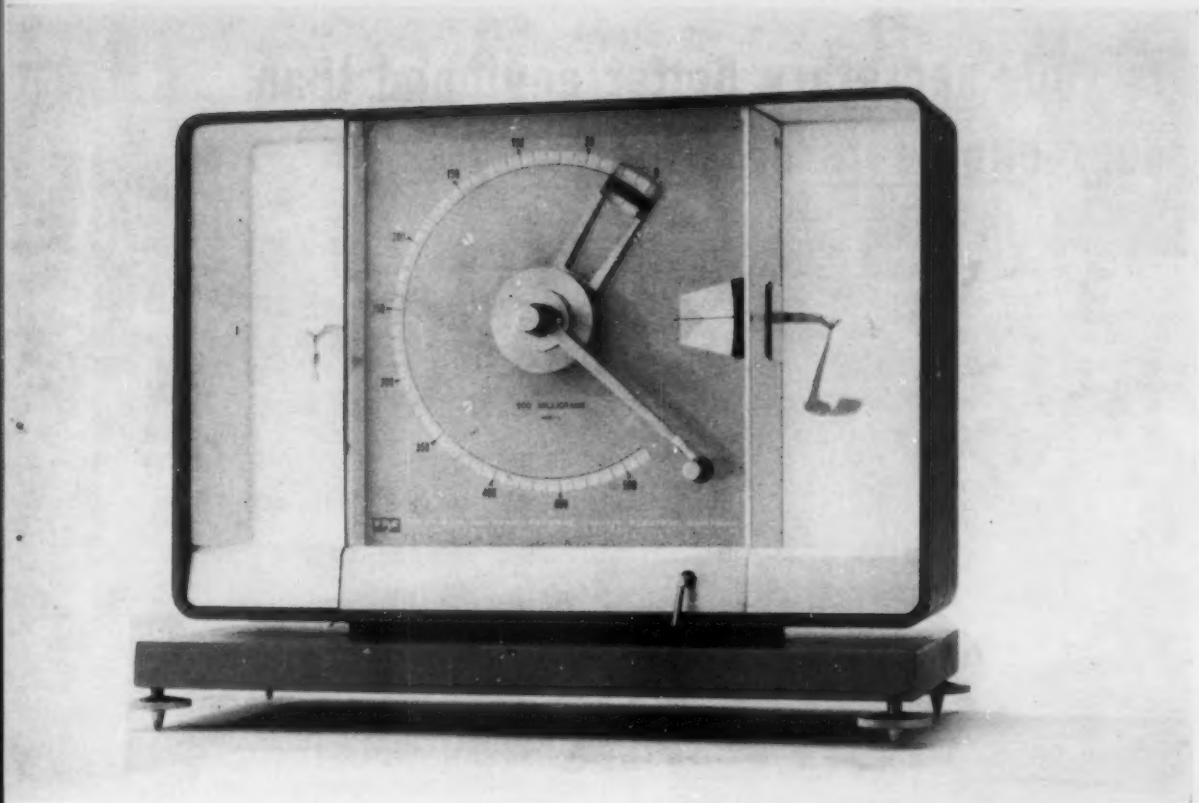








■ When Federal Pacific Electric Co, Newark, NJ, acquired Roller-Smith Co, it took over rights to a precision balance (top, this page) that has enjoyed wide acceptance for the past 50 years in such diverse applications as laboratories, production lines and quality-control systems. But to meet the competition of more recently designed competitive equipment, redesign was indicated to reflect some of the newer concepts of scale readability, accessibility of weighing compartments, and ease of adjustment and maintenance. This had to be done while maintaining—or even enhancing—the instrument's look of precision The only

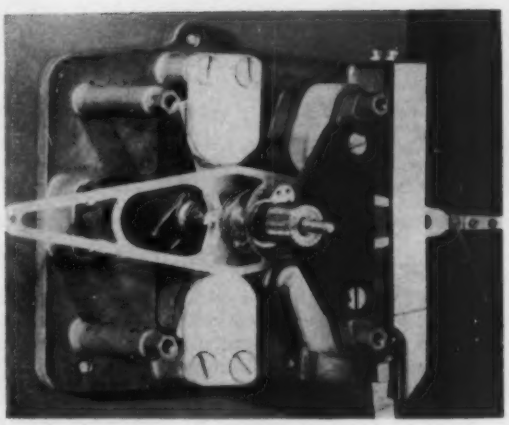


engineering changes planned were concerned with simplifying assembly and calibration.

The industrial designers, Raymond Loewy-William Snaith Assoc, NYC, experimented with a number of approaches to the housing (sketches, facing page) before they settled on a design approach based on a single, integrated rectangle. Projections of the two models finally presented to Federal Pacific are shown at left.

The new balance's die-cast aluminum housing (top of this page) follows these final proposals closely. Compartments that protect weight-hooks from air currents, dust and other accuracy-impairing factors are held closely by magnetic latches. These compartments are painted white for maximum illumination and rear panels are translucent glass, to modulate light sources and obscure extraneous objects behind balance.

Color has been used to define calibrations and distinguish between vernier and reading scale.



In the older model, all assembly work was done by inserting tools through side openings while operator viewed work from front. Now the balance movement (right) is completely exposed while assembly and calibration take place on the back plate. Plate and movement are then secured to base for final assembly of housing and weight-hook compartments.■ JK

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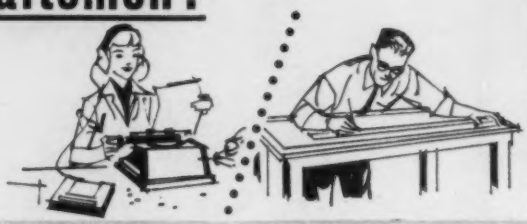

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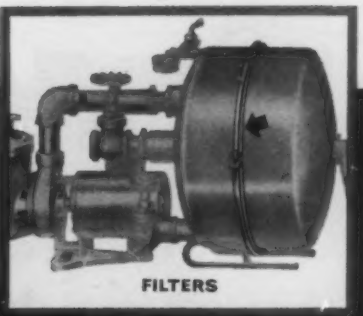
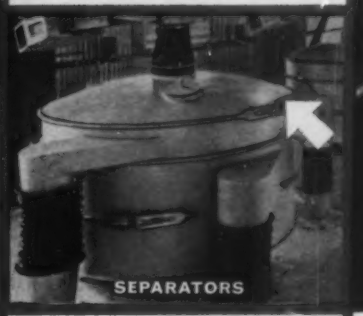


FILTERS



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Leading Manufacturer of
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Left to Right: Jim Lawless, Hallicrafters' Chief Draftsman; Mark Pogue, Reproduction Department Head; Frank Krautsak, Bruning Representative.

"Bruning helps, *two ways*, to meet Tight Government Deadlines!"

"It's the *extras* we get from people and equipment that help us meet tight government QRC* contract deadlines," says Jim Lawless, Hallicrafters' chief draftsman. "Bruning products and service are good examples. We've run our Copyflex reproduction machines an average of 77 hours a week. Yet, we've never had a delay because of machine failure, maintenance, or lack of materials. Another big extra has been the help of the Bruning Representative who has saved us many hours of work with everything from intermediates to electric erasers."

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CIRCLE 28 ON READER SERVICE CARD

READER TO EDITOR

US Standards Groups Do Their Bit

To the Editor:

Numerous American engineers will commiserate with the four gentlemen who in "Points of View" (*Dec. 19 '60 p 20*). gave their views on American standards Disregarding the economic aspects of their plaints, many of us will agree that their criticisms are valid in principle. However, I must take exception to some remarks by T. R. B. Sanders, engineering advisor, British Standards Institute. He said:

"More than ten years ago, the ABC countries (America, Britain and Canada) agreed to adopt unified threads. Britain confirmed these new standards in 1953, but America did not publish a separate standard for unified threads until this past summer. The result—manufacturers in other countries have hung back, waiting for American implementation. Britain carried on with Whitworth threads. What else could we do?"

Mr Sanders' statements puzzle me because to my knowledge, all the following authoritive and governing publications on the Unified & American System of threads were issued prior to "last summer" (I am assuming that "last summer" refers to the summer of 1960):

1. ASA BI.I-1949 by American Standards Association.
2. 1950 Supplement to Screw Thread Standards for Federal Services (Handbook H28), by the National Bureau of Standards.
3. MIL-S-7742 July 1951 for Army, Navy and Airforce procurement.
4. 1957 Screw Thread Standards for Federal Services (Handbook H28) by the National Bureau of Standards.

I therefore do not believe that we were as culpable or as lax as Mr. Sanders implies in implementing the Unified & American System of threads. —H SCHLARMAN
Los Angeles

Automated Draftsmen?

To the Editor:

After reading your article on the "Draftsrobot," (*Jan 20, p 15*) I was wondering how soon a machine would replace us "Board Jockeys"? However, after noticing two lines missing from the front elevation view, I think we will be around for a while longer. —STEPHEN KOROL
Diversified Engineering Lab
Detroit

Too Fast to Learn

To the Editor:

The letter from Mr Daly which derides the PhD degree (*Jan 23, p 26*) would have been better if he had given some constructive ideas as well. Too often, and as Mr Daly states, that degree is so narrow and restrictive that the person holding it offers little competence to a prospective employer.

We do need postgraduate study. Knowledge is doubling every few years, 10 years in engineering as a whole and faster in physics, and it is impossible to learn enough in the usual 4-year course of

study. I am a believer in postgraduate study, but feel that such study should still emphasize the basic sciences of physics, chemistry, mathematics, etc. Specialization is wasted effort during college study. We are progressing so fast that specialized study is obsolete in 5 to 10 years anyway.

—T B Holliday
Elmhurst, Ill

CORRECTION

To the Editor:

In my article "How Linear are Flow-control Valves?" (*PE*—Feb 6, p 47) two printing errors occurred. The first equation should read

$$Q = CA\sqrt{2gh}$$

and equation for Fig 7 should read

$$A = 2\left[r^2 \cos^{-1}\frac{\left(r - \frac{x}{2}\right)}{r} - \left(r - \frac{x}{2}\right)\sqrt{2r\,\frac{x}{2} - \left(\frac{x}{2}\right)^2}\right]$$

—Louis Dodge
New Richmond, Ohio

COMING EVENTS

MARCH

20-23 . . . . Institute of Radio Engineers International Convention, Waldorf-Astoria Hotel & NY Coliseum, NYC

20-24 . . . . American Society for Metals, 12th Western Metal Congress & Exposition, Ambassador Hotel & Pan-Pacific Auditorium, Los Angeles

27-31 . . . . Instrument Society of America, National Bureau of Standards, American Institute of Physics, Temperature Measurement and Control, Veterans Memorial Building, Columbus, Ohio.

APRIL

4-7 . . . .Society of Automotive Engineers, National Aeronautic Meeting and Missiles and Aircraft Engineering Display, Commodore Hotel, New York

5-7 . . . .Institute of Environmental Sciences, Annual Meeting and Equipment Exposition, Sheraton Park, Hotel, Washington, DC

11-13 . . . . American Society of Lubrication Engineers, Annual Meeting and Exhibit, Bellevue-Stratford Hotel, Philadelphia

20-21 . . . . Society of the Plastics Industry, 18th Annual Western Section Conference, Hotel del Coronado, Coronado, Calif

For a listing of addresses of societies and associations send 25¢ to Product Engineering Reader Service Dept, 330 W 42nd St, NY 36. Ask for brochure R 32.

CASE HISTORY NO. 106

Fluting and Leak-proof Assembling

...tricky jobs but well within our capabilities

These are specially designed strainers, utilizing 100 mesh stainless steel cloth. The fluting provides maximum filtration areas for specified diameters.

The problem in fluting was to form the piece, which has only one joint and at the same time retain mesh integrity at the bends. The problem in the assembly was to provide against leakage from under the retaining rings.

These strainers are indicative of the kind and quality of work we do in our fabricated parts division. We've handled many other tough forming and assembly jobs. Simple ones are routine.

If you are not satisfied with the way your mesh-assembled parts are being turned out, why not let our skilled workers take over the job? We'll be glad to study your model or drawings and discuss the problem with you. Perhaps we can point out a better or simpler way to assemble the parts without loss of efficiency.

NEWARK for ACCURACY

Newark Wire Cloth COMPANY

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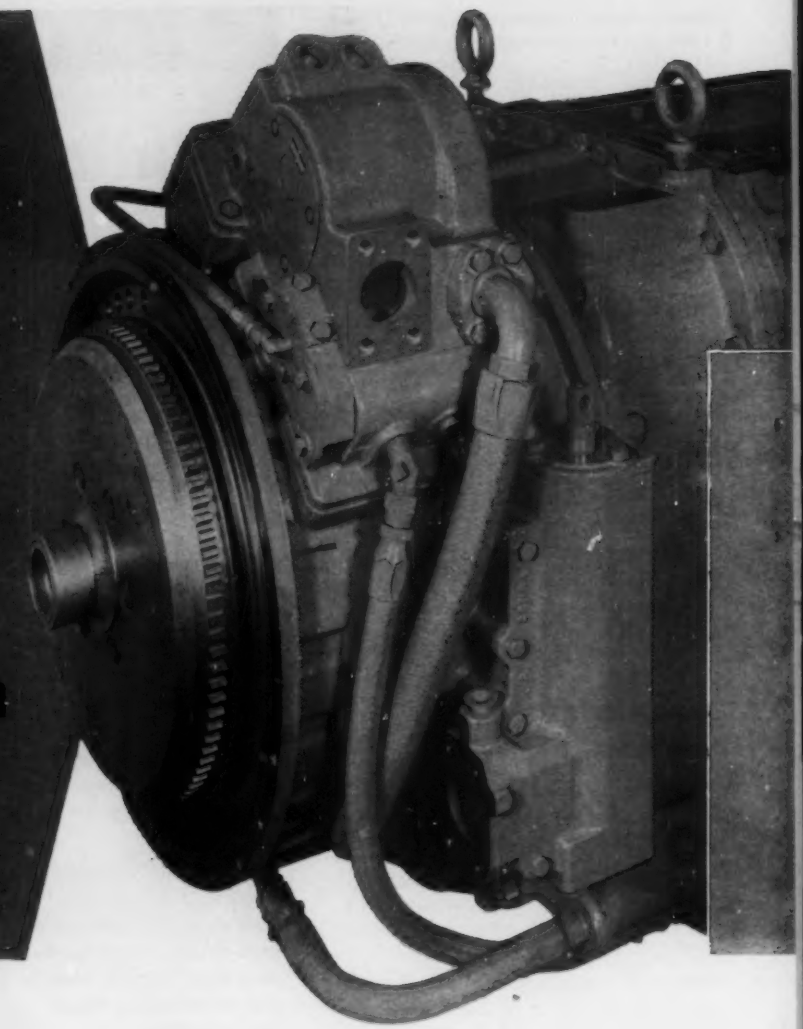
NEW Torque Converter and Constant-Mesh Transmission



Designed SPECIFICALLY for

TWIN DISC, which introduced America's first torque converter in 1936, has a wealth of experience in designing converters for such applications as construction machines, oil rigs and logging equipment. But in designing the 18″ converter for a new power-shift transmission package for heavy-duty vehicles, Twin Disc engineers had to solve a number of special problems.

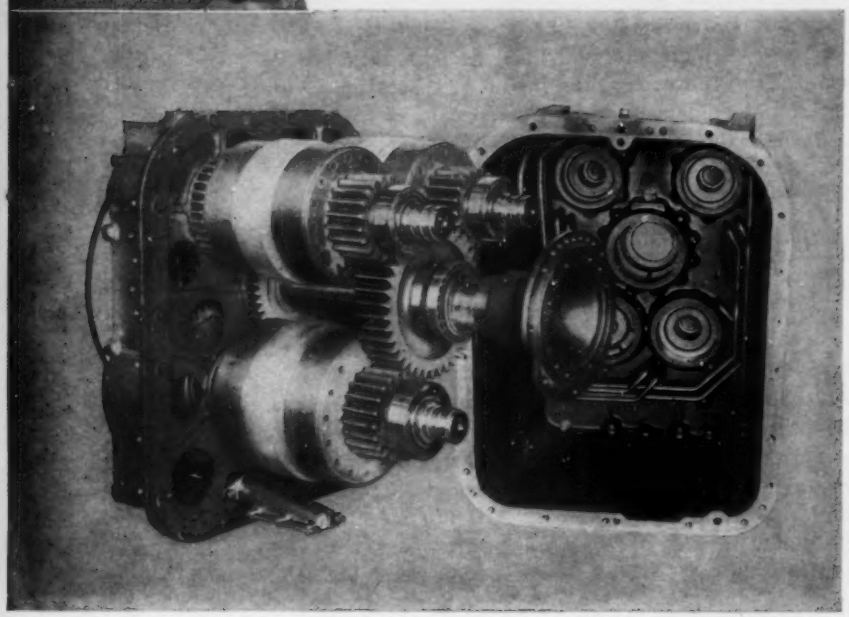
There are long stretches when a truck does not require torque multiplication. For peak efficiency during these periods, Twin Disc has included a freewheeled stator in its new single-stage converter. When the need for torque multiplication falls off, the speed of the pump wheel approaches that of the turbine. This reduces the reaction force on the stator to the point where it freewheels. The converter becomes in effect a fluid coupling, and the result is higher efficiency.

This efficiency can be stepped up still further under 1:1 ratio conditions by means of a front-end lock-up clutch on the converter. Engagement of this clutch provides direct drive performance.

Also featured in this new converter is a hydraulic retarder. Loads on truck service brakes keep going up, yet their capacity is limited by the available brake space at the wheels. The hydraulic retarder absorbs a high percentage of the vehicle's kinetic energy, dissipating it in heat. This saves wear on the brakes and permits safe, controlled descents at higher speeds.

The torque converter can be supplied as a separate unit or as part of a converter-transmission package with the new Twin Disc TA-51-2000 Power-Shift Transmission. This transmission permits gear-shifting on up-hill hauls without power interruption or loss of momentum.

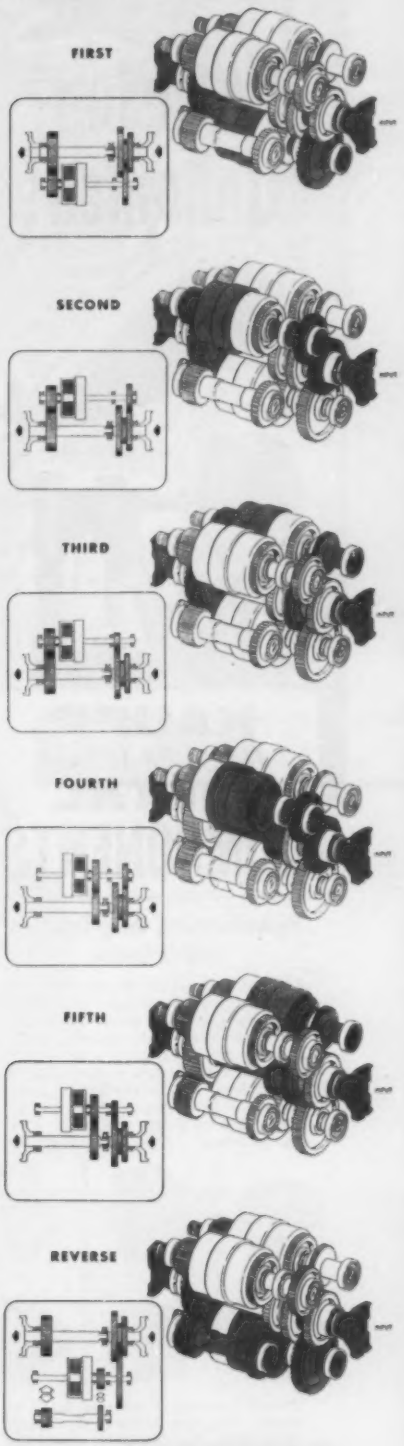
The TA-51-2000 is a straight-through countershaft unit with constant-mesh gearing. Shifting in all ranges at full engine power is



Three models available in the TA-51-2000 Series

Model No.	Max. HP	Max. Torque (lb.-ft.)	Max. Speed (rpm)	Ratio Spread
TA-51-2001	420	1050	2500	5.93:1
TA-51-2002	420	1050	2200	6.80:1
TA-51-2003	420	1050	2800	5.45:1

Transmission Power Flow



Vehicles...by TWIN DISC

through multiple-disc, oil-cooled, hydraulically actuated clutches. There are five forward ratios and one reverse. A modified version, called the TA-33-1600, has three forward and three reverse speeds. Four different drop boxes are available to meet special drive requirements.

The converter is used only in the first two ranges to get the load moving or to meet low-speed tractive-effort demands. The second ratio has two selector positions, one for drive through the converter and the other for use when the converter is locked up. Lock-up range thus extends from the second through the fifth ratio. Where desirable, a manual over-ride can be provided to permit converter drive in all ranges.

A noteworthy feature of these converter-transmission packages is interchangeability of parts. Gearing can be easily changed to match engine modifications, thereby simplifying inventories and service.

Twin Disc Clutch Company, Racine, Wisconsin; Hydraulic Division, Rockford, Illinois.

ENGINE TO AXLE WITH... TWIN DISC POWER TRANSMISSION EQUIPMENT

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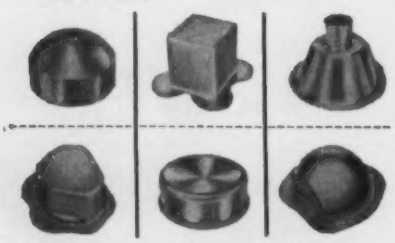
PRECISION-FORMED
METAL
COMPONENTS

Hydroforming, Deep Drawing and Spinning

You can depend on KAUPP for complete service from design to delivery on precision-made metal parts and sub-assemblies. Ultra modern metal working facilities, plus wide experience on military and commercial requirements are available to solve your problems. Send drawings for quotations or phone for new illustrated bulletins!



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WHY DON'T THEY R&D..?

The following suggestions are extracted from the latest (Dec '60) edition of "Inventions Wanted by the Armed Forces." If you have an answer to any of these problems, or if you would like a copy of this booklet, write: National Inventors Council, US Dept of Commerce, Washington 25, DC.

. . . a high-torque, low-noise speed reducer for torpedos. Noise in torpedos gives away their position and interferes with their acoustic-guidance equipment. Because torpedos have only one power source driving a variety of mechanisms at different speeds, speed reducers and increasers are required. Gear reducers are noisy despite attempts to silence them with precision gearing, sleeve bearings, dynamic isolation between gear meshes, accurate balancing and vibration mounts. Speed reductions in the range of 50:1 are needed. The reducer should generate a minimum of noise in the band between 0 and 50 kc and should be capable of handling 50 to 1000 hp. Perhaps a belt drive, roller drive or cycloid drive could be adapted to the job.

. . . a remote detonator for explosive shells fired onto a beach from an offshore ship. Tactically, such a device would greatly help "soften up" a beachhead; shells could be planted over a large area and exploded simultaneously just before the first wave of troops landed. Present remote detonators do not allow simultaneous detonation and have the further disadvantage that the enemy can remove the shells or use decoys to explode them; so the detonation mechanism must also be made tamperproof. It is suggested that shells contain a time mechanism to render them shock-sensitive once on the beach and a remote-firing device that would permit them to be detonated only by friendly forces.

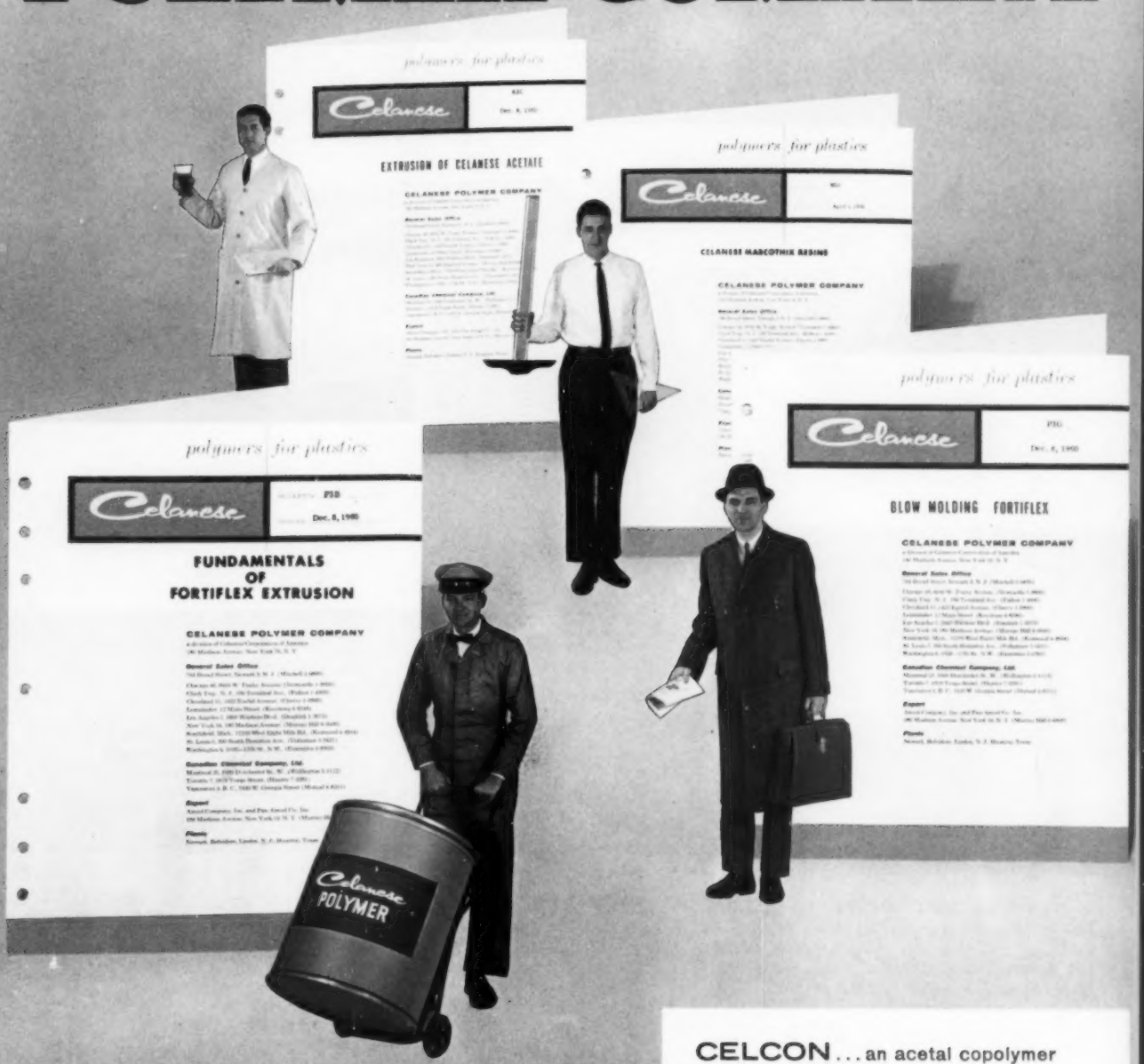
. . . a self-priming electric bilge pump for tanks and other tracked vehicles. In the present design, centrifugal pumps are used because of the large amount of sand and other foreign matter that must be pumped along with the water. These pumps are placed low in the bilge to reduce the need for priming, but they don't always work. And the debris damages the impeller, shortening pump life. Needed: a unit that overcomes present objections and would also double as a fuel-transfer pump. It should deliver at least 100 gpm at a 10-ft head, operate on 24 v dc, and last at least 1000 hr.

. . . a pocket-size detector that will warn its user of lethal concentrations of electromagnetic radiation. The maximum permissible human tolerance to different frequencies is not completely known, but it is thought that a detector indicating power levels in excess of 0.010 watts/cm^2 in a band between 500 and 15,000 megacycles would be adequate. Warning should be audible, vibratory or thermal.

. . . an air heater for testing air-breathing engines. It should be able to deliver 3 lb/sec at temperatures between 2000 and 6500 F, and pressure from 500 to 2500 psi for periods up to 2 minutes. The practical upper limit of tube-and-shell heat exchangers is thought to be about 1900 F. Experimental heaters, in which air is forced through heated zirconium oxide pebbles, have been made, but life is short and maximum temperature less than 6500 F.

Have you a problem, based on known scientific principles, which seems to have an answer somewhere within the limits of present technology? To inspire inventors along worthwhile paths, PRODUCT ENGINEERING invites you to trade such problems with fellow readers who have a fresh viewpoint or more time to experiment. We pay $10 for each one accepted.

CELANESE
POLYMER COMPANY



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Here's a plastics service with just one purpose . . . to help you make the best possible product at the lowest practical cost. It starts with your local Celanese representative. His helpful, friendly service is backed by quality plastic materials . . . specialists in design and molding techniques . . . the newest and finest laboratory in the industry. Celanese Service-In-Depth is always available to you. Why not profit by it now!

Celanese Polymer Company is a Division of Celanese Corporation of America

CELCON . . . an acetal copolymer

FORTIFLEX . . . high, medium and low density and flame-resistant polyethylene

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TECHNICAL SERVICE

DESIGN ASSISTANCE

A design consultation with your Celanese representative is the best start to trouble-free molding, and better products. He can suggest ways to speed production by *avoiding* troubles at the design stage—where they often start. And when new and unexplored applications come up, he will help you make decisions based on experience, facts, and tests.

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Celanese POLYMER MOLDING COMPOUNDS AND RESINS

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Celcon is a new, high-performance engineering material. It offers excellent processability . . . superior heat and cold resistance . . . stability under long service . . . excellent resistance to chemical attack. Use Celcon as a replacement for metals and other plastics.

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Available in all densities . . . natural or color-matched to your specifications. Four basic Fortiflex types for housewares, appliances, automotive, coatings, pipe, toys, film and sheet.

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Forticel—excellent balance of properties . . . toughness . . . dimensional stability . . . moldability. Acetate—rugged . . . versatile . . . economical. Both available in a variety of formulations, unlimited colors. The only thermoplastics combining both toughness and transparency plus economy.

POLYESTER RESINS

Celanese polyester resins are outstanding for formulating and molding pre-mix and matched die preform parts. They offer fast cure, low drainage, better wet-out for hand lay-up. Save time and labor on critical large area moldings . . . boats, doors, truck bodies, housings.

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Celanese offers cellulose acetate, cellulose triacetate and cellulose propionate flake in a variety of grades, to basic industries such as plastics, sheet, film, fibers, coatings and adhesives.

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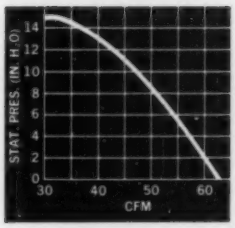

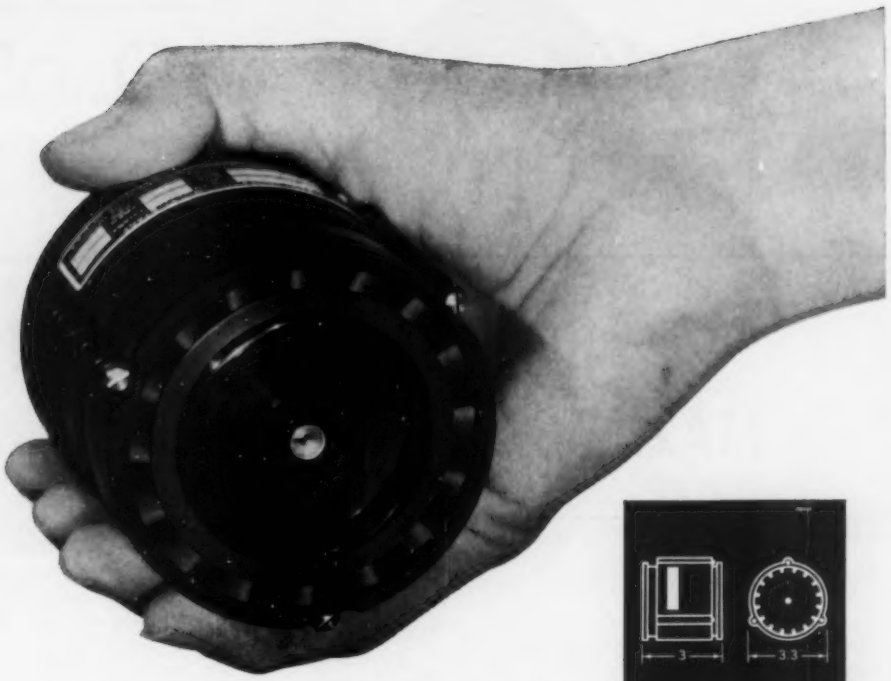

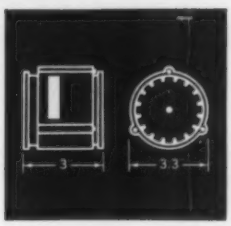

MULTI-STAGE BLOWER THIS SMALL?

New Globe multi-stage blowers drive cooling air against the extreme pressure resistance you encounter in heat exchangers, tightly packed black boxes, and crammed transistor circuitry. They deliver 39 cfm against 14" H_2O back pressure! (65 cfm free air.) With STAX-3-FC blowers you can design right past costly devices and heavy centrifugal air "pumps" (that use ¼ hp or more for comparable volume/pressure). And you can keep the **whole** package small. A limited number of units are stocked for prototype quantity delivery to you in 24 hours.

With a low specific speed (Ns = 15,000) STAX blowers perform far past the stall regions of other axial blowers. Unique dynamically balanced rotor design permits the use of one, two, or three stages in the same size package. Motor operates on 200 v.a.c., 400 cycle, three phase power. Units are designed to meet applicable MIL specs; nominal continuous life is 1000 hours. Weight: 29 oz. (3-stage). Production tooling keeps the price within reason. If you need more performance, different power, etc., Globe will design the exact multi-stage blower you require.

The powerful STAX is one of hundreds of miniature blowers made by Globe and engineered for **your** application. Request Bulletin STX, or call direct: Globe Industries, Inc., 1784 Stanley Avenue, Dayton 4, Ohio. BAldwin 2-3741.

GLOBE INDUSTRIES, INC.

PRECISION MINIATURE A.C. & D.C. MOTORS, ACTUATORS, TIMERS, CLUTCHES, BLOWERS, FANS, MOTORIZED, DEVICES

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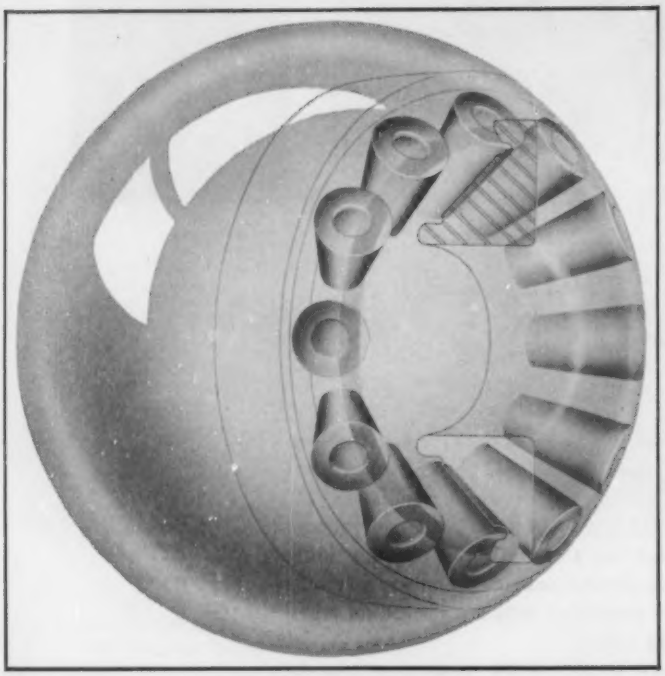
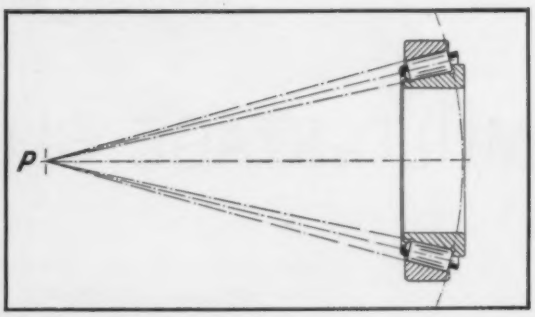
One in a series of technical reports by Bower

BEARING BRIEFINGS

SPHERICITY — ESSENTIAL TO MAXIMUM BEARING PERFORMANCE



When you require bearings, we suggest you consider the advantages of Bower bearings. Where product design calls for tapered or cylindrical roller bearings or journal roller assemblies, Bower can provide them in a full range of types and sizes. Bower engineers are always available, should you desire assistance or advice on bearing applications.



True rolling of tapered bearing elements depends upon maintaining a true spherical radius during manufacture.

For a tapered roller bearing to achieve maximum performance, i.e., maximum life and capacity under load, it must have true sphericity — a condition of bearing geometry which permits true rolling of the tapered rollers in the raceway.

True rolling in tapered bearing elements is the result of maintaining a critical geometric relationship between the raceways and the contact surfaces of each roller. True rolling is essential to maximum performance. Without it, premature bearing failure is certain.

As engineers know, a tapered roller will describe a true circle when rolled on a plane surface. *It will always roll in this one path precisely, without sliding or skewing.* But to put true rolling to work in a bearing which can carry both heavy thrust and radial loads, it is essential that the rollers *and* the raceway have a true spherical radius, or sphericity. The drawing illustrates this condition.

If each roller in the bearing were to be extended in length, while retaining its taper, it would form a cone, terminating at point "P". All cones generated from all rollers would meet at point "P", which is also the center of the hypothetical sphere shown. The surface of the sphere would *touch all points on each roller's head!*

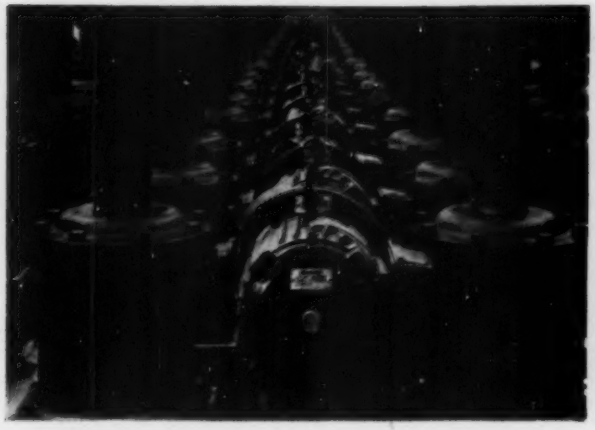
In effect, then, each roller's taper determines the radius of a hypothetical sphere whose surface, in turn, determines the correct contour for each roller head. Only when these conditions are satisfied in design, and when they are rigidly held during manufacture, will true rolling take place. In the manufacture of each Bower tapered roller bearing, sphericity is held within extremely narrow limits by means of special Bower-designed precision grinders. The consistent accuracy possible with these machines is one major reason why Bower roller bearings provide maximum performance under all speeds and loads up to the bearing's maximum rating.

BOWER ROLLER BEARINGS

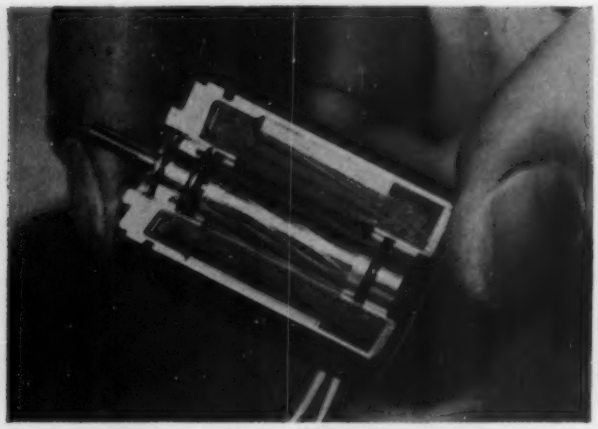
BOWER ROLLER BEARING DIVISION — FEDERAL-MOGUL-BOWER BEARINGS, INC., DETROIT 14, MICHIGAN

SILICONE NEWS from Dow Corning

How To Get More Drive...



When the heat's on! Engineers for the Harvey Aluminum smelting plant at The Dalles, Oregon, take no chances on the reliability of anode feed motors in the electrolytic cell section. *Ambient temperatures are in the order of 300 F.* Harvey engineers specified Dow Corning silicone insulation for all 960 of the motors. Operated intermittently to adjust the carbon electrode level, these motors have the thermal stability to assure reliability despite the combined heat of high ambient and motor load.



From miniature motors! This servo motor intended for high temperature and humidity service has "sealed in" dependability with Dow Corning silicone insulation. Engineers at G-M Laboratories, Inc., Chicago, specify that the stator coils of this unit will be vacuum impregnated with Dow Corning solventless silicone resin and cured in an inert atmosphere. The cutaway picture shows how the resin completely fills the coil interstices and provides a solid bubble-free mass . . . seals out trouble.

Where the going is rough! Two 20-horsepower, a-c traction motors with Dow Corning silicone insulation keep mine production moving in spite of severe overloads and high temperatures. Goodman Manufacturing Co., Chicago, uses these motors on their four-wheel drive "584" shuttle car to assure the extra overload capacity needed for long life . . . dependable, easy, safe operation. If you need rugged motors for tight spots, specify Dow Corning silicone insulation.

For a reverse twist! On jobs that call for numerous drive reversals, you'll find Dow Corning silicone insulation eliminates frequent motor burn outs. Cadillac Gage of Detroit did. The motors—1-hp, 1800 rpm, Class A insulation—were required to make up to 100 reversals per minute. This created too much heat for the Class A insulation. Since putting silicone insulation to work, Cadillac Gage has not reported a bit of trouble with these lathe motors.

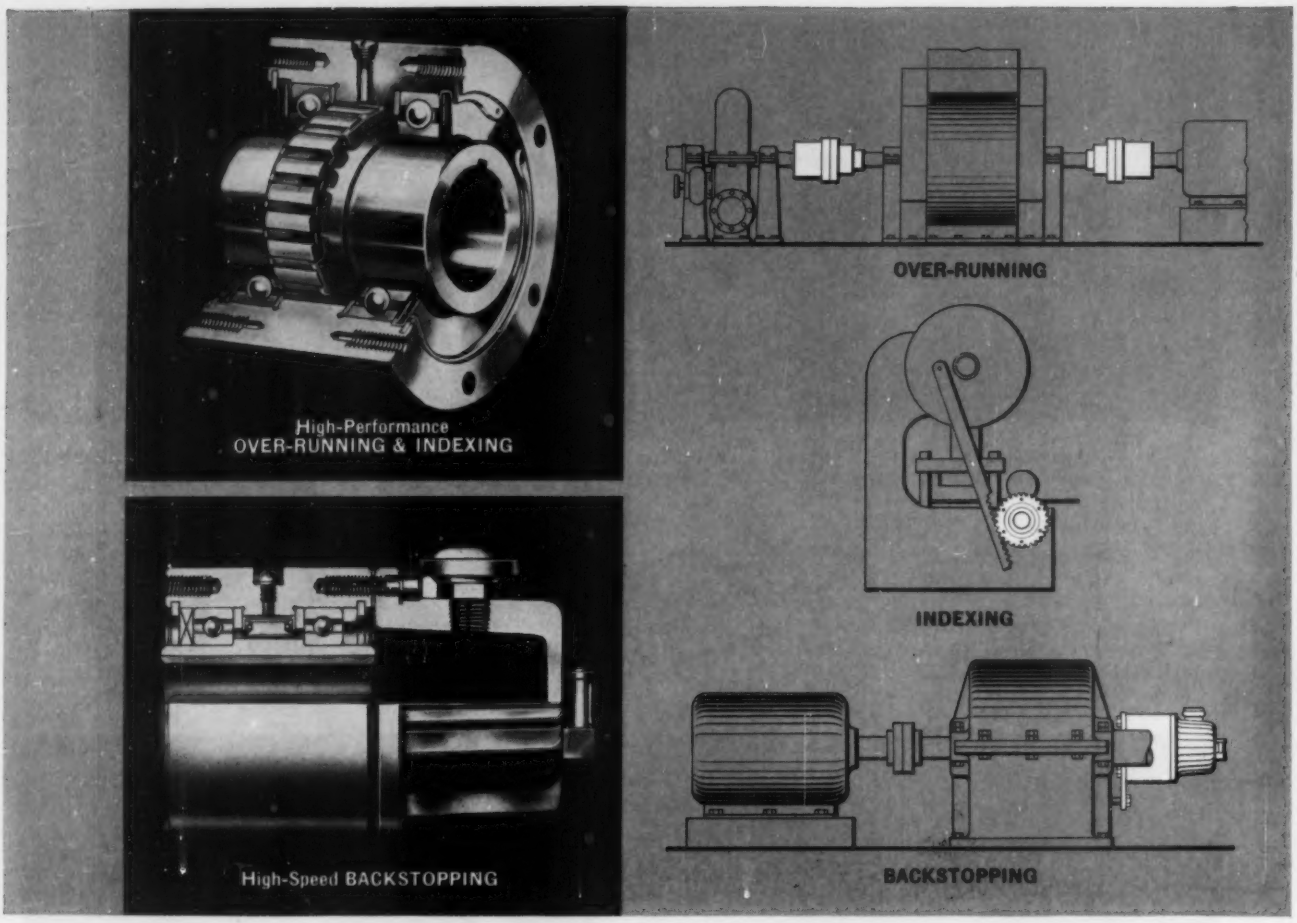
For the complete story on silicone insulated drives, write Dept. 7215a.

first in silicones

Dow Corning CORPORATION
MIDLAND, MICHIGAN

ATLANTA BOSTON CHICAGO CLEVELAND DALLAS LOS ANGELES NEW YORK WASHINGTON, D. C.

FORMSPRAG Clutches have



These Installations Prove Formsprag Has The Most Advanced Clutch Designs Available

On tough applications requiring high-performance over-running, indexing or backstopping, Formsprag clutches have *proved* their unusual durability, precision and reliability. Their long-life and minimum maintenance requirements, even under unusually demanding installation conditions, have provided many users with the answer to their clutch problems. Compare the following performance results on actual installations—Formsprag designs can help you, too!

High-Performance Over-Running

Application:
Forced and Induced Draft Fans.

Clutch and Mounting:
Model FO-732 Clutch-coupling (HPO-720 clutch with coupling) mounted on fan drives.

Requirements:
Continuous over-running at 1200 to 1800 R.P.M. (24 hours a day, 365 days a year).

Proved Results:
The Formsprag HPO clutch design with Formchrome sprags provides this company with greater durability and less maintenance than any other available clutch. Therefore, on all forced and induced draft fans, this manufacturer specifies Formsprag high-performance over-running clutches.

Precision Indexing

Application:
High Speed Press.

Clutch and Mounting:
Model HPI-700 feeding a progressive die.

Requirements:
20° indexing; feed is 700 strokes per minute; accuracy of feed must be within .005″; press operates 24 hours a day, 5 days a week.

Proved Results:
After poor service life and unreliable results from other clutch designs, a Formsprag high-performance indexing clutch was installed. Result—customers requirements for accuracy were met, clutch has had a life of 80 million cycles and is still running.

proved higher performance

(GREATER TORQUE & SPEED, HIGHER PRECISION, LONGER LIFE)

During the last two years, Formsprag has announced several major advances in over-running clutch design. These advanced concepts have been widely accepted by designers of modern power transmission systems. The high performance results they obtained on over-running, indexing and backstopping applications *prove* Formsprag clutches to have the most advanced designs available.

On-the-job records *prove* these high performance characteristics: (1) Formchrome sprags, with high-hardness and wear resistance, provide exceptional durability—no other manufacturer can offer the performance advantages of Formchrome sprags. (2) The improved sprag and retainer design of Formsprag High-Performance Over-running (HPO) and Indexing (HPI) clutches permit up to 30% higher operating speeds with same life span and up to 70% longer clutch life when operated at same RPM as ordinary clutches. (3) On backstopping applications, the High-Speed Backstopping (HSB) clutch design permits higher speeds, assures longer life and reduces maintenance to a minimum.

Specific case-history data on *proved* over-running, indexing and backstopping installations is provided below. In every instance, users of Formsprag High-Performance Clutches have found the answers to problems of wear, high-speed operation, precision and maintenance.

There is a Formsprag Clutch for every application. Standard models include: sleeve bearing, ball bearing, miniature, large-bore holdbacks, and high-performance types. For special applications, Formsprag engineers will recommend a modified standard clutch or design a special. Standard clutches are fully described in the Formsprag catalog—send for your free copy.

FORMSPRAG COMPANY

23607 Hoover Road, Dept. 114-A — Warren (Detroit), Michigan

Representation Throughout The World • Precision Power Transmission Products

High-Speed Backstopping

Application:
Iron Mining (Taconite) Conveyor.

Clutch and Mounting:
Model HSB-700 clutch assembly mounted on high-speed shaft of reducer.

Requirements:
In abrasive atmosphere, clutch must over-run at 1200 to 1800 R.P.M. (24 hours a day, 9 months of year).

Proved Results:
On this rugged backstopping application, Formsprag HSB clutches solved problems of overheating, premature seal wear, and short clutch life. These high-speed backstopping clutches have been in operation for over a year and are still delivering their initial high performance.

OTHER FORMSPRAG PRECISION PRODUCTS

NEW RAWSON

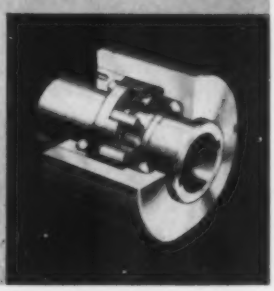
CENTRIFUGAL CLUTCHES and CLUTCH-COUPLINGS

Used in a wide variety of applications, the Rawson design provides no-load starts for motors and cushioned starting of driven equipment. They permit using smaller motors and across-the-line starting.

REVLOK

DUAL TORQUE-LOCKING and POSITIONING DEVICES

These multi-purpose devices stop feedback torque and provide two-directional positioning, over-running, backstopping and load-limiting. They can also be adapted for single revolution and torque-limiting functions.



Engineering Data

WINSMITH SPEED REDUCERS

HOLLOW SHAFT WORM GEAR SPEED REDUCERS

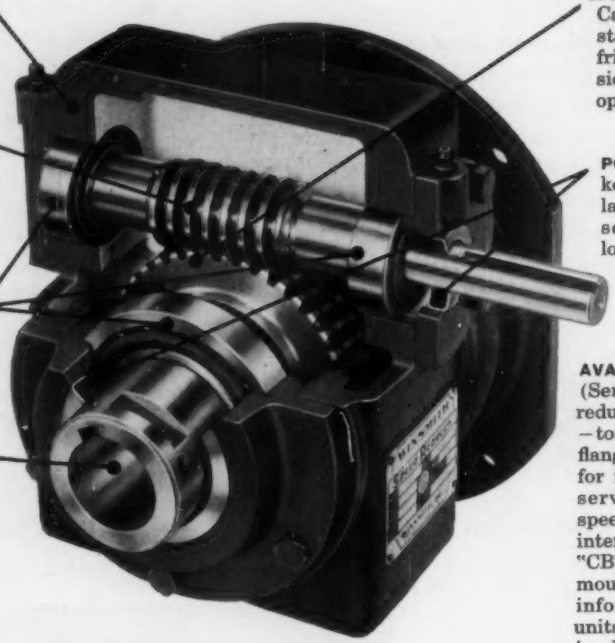
single and double reduction . . . torque arm and flange mounted models

CAST IRON HOUSINGS designed for high heat radiation. One-piece construction, close-grained gray iron for maximum strength and rigidity.

CASE-HARDENED STEEL WORMS cut integral with the shaft. Heat treated for close-grained tough core, carburized and hardened before grinding. Meet AGMA long-wear specifications.

TAPERED ROLLER BEARINGS for minimum maintenance, long bearing life and permanent shaft alignment. High radial and thrust load capacity.

HOLLOW SLOW SPEED SHAFTS in wide range of standard bore sizes and keyways. Mounts on shaft of driven machine *without bushings*—two external slots facilitate removal with standard wheel puller.



SPECIAL BRONZE WORM GEARS Cast to recommended AGMA standards. Low coefficients of friction and thermal expansion for cooler, more efficient operation.

POSITIVE OIL SEALS keep oil in, dirt out. Shafts lapped to micro-finish under seals for uniform contact, longer seal life.

AVAILABLE in single reduction (Series ST and SF) and double reduction (Series STD and SFD) —torque arm ("T" models) and flange mounted ("F" models)— for intermittent or continuous service. Hollow shaft slow speed assembly of "ST" series interchangeable with Winsmith "CB" and "CT" Series with foot mounted housings. For further information on these latter units, write Winsmith Engineering Department.

- *12 Models*
- *.041 to 8.82 H.P.*
- *Ratios 7½:1 to 4466:1*
- *Max. Output Torque 816 to 7678 in. lbs.*

Winsmith Hollow Shaft Speed Reducers cover a broad range of power transmission requirements for both single and double reduction drives. *Their worm gearing provides much higher reduction ratios than are possible in comparable size units using other types of gearing.* Winsmith Hollow Shaft models are designed for all applications where it is advantageous to mount the reducer on the shaft of the driven machine. They are compact, easy to install and require less space than conventional units. Their design and construction provide high shock load resistance; maximum thermal capacity without induced cooling; greater overhung capacity; and a high degree of standardization which eliminates excessive special application engineering.

Write today for complete information or call your nearest Winsmith Representative listed in the Yellow Pages. He is a technically trained expert who is always ready to help you with any speed reducer problem. For both standard and special power transmission applications, you'll find it pays to standardize on Winsmith.

WINSMITH, INC.

208 Eaton Street, Springville, (Erie County), New York

MEMBER OF AGMA

• • • Winsmith Speed Reducers are made by American craftsmen to meet American design and production standards.

Truarc Rings ... installed with these Truarc tools ... enable Revere Camera Co. to speed assembly ... and improve servicing of its tape recorders. Result: Revere now uses Truarc rings on all its quality recorders, cameras and projectors.

PRODUCTION PROPOSITION: Let a Truarc representative study your production line set-up soon. He can show you exactly how Truarc rings and assembly tools can help save time, money, and materials besides lowering the final assembled cost of your product. Call him and see. Catalog AT 10-58 shows the complete line of Truarc rings and assembly tools that can be used on your production line profitably. Write for it today. Your nearest **Authorized Truarc Distributor** is as close as your telephone. For immediate action, check your Classified Telephone Directory under: "Rings, Retaining." O.2

WALDES

TRUARC® RETAINING RINGS

WALDES KOHINOOR, INC., 47-16 Austel Place, Long Island City 1, N. Y.

9 OUT OF 10 PRODUCTS CAN BE IMPROVED WITH TRUARC RETAINING RINGS

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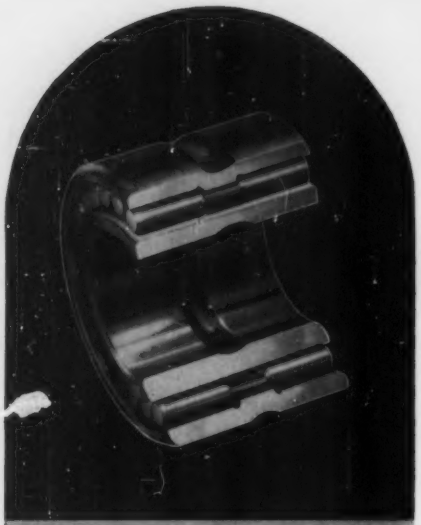


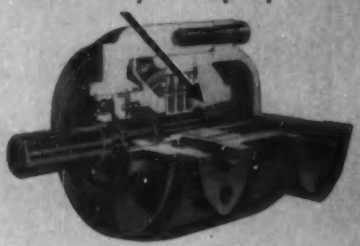
McGILL® GUIDEROL® BEARINGS

pack more capacity in less space

- *Center-guided rollers limit skewing tendency, prevent binding*
- *Integral seals increase life — avoid frequent relubrication*

GUIDEROL bearings provide the maximum load carrying surface and minimum radial dimension advantages of full-type roller bearings — plus free and accurate tracking where misalignment is controlled. They are especially suited to vertical mounting. Sealed models keep out abrasive and lube-diluting contaminants — and avoid relubrication problems. These heavy duty units are available with or without inner races with bore sizes from ½" to 9¼". Typical applications and their advantages are shown below.

GUIDEROL® compactness and high load capacity utilized in DENISON hydraulic pumps



The Denison Engineering Division of American Brake Shoe Company cites compactness, high load capacity and separable design as advantages of the McGILL GUIDEROL bearings which they use to carry externally applied loads in their "T" Series Balanced Vane Hydraulic pumps. Denison Engineering also state that they have benefited from "Good delivery and cooperation from McGILL Engineering on new development."

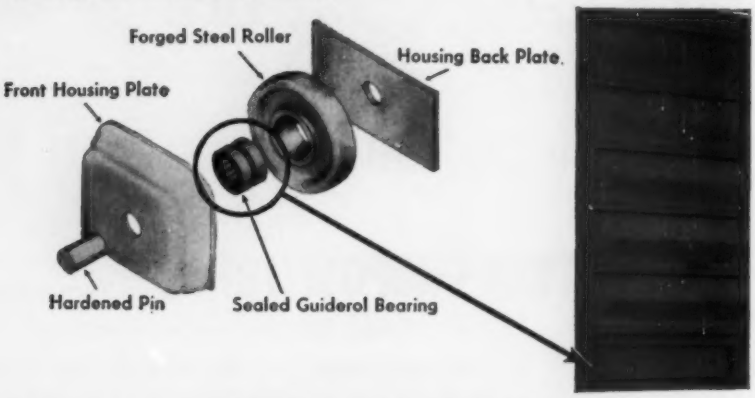
Typical applications of Denison "T" Series Balanced Vane Pumps are for continuous 2000 psi service in earthmoving equipment, and similar types of mobile equipment; special machinery, such as extrusion presses and in automation feed service and index mechanisms.

Integral seals protect operation of GUIDEROL® bearings in PULLMAN-STANDARD box car door rollers

Pre-lubricated and sealed GUIDEROL bearings are used in the door roller assembly shown here by the Pullman-Standard Car Manufacturing Company to assure ease of operation in spite of exposure to severe service conditions. Integral seals prevent infiltration of dirt and retain lubrication thus minimizing maintenance.

This roller arrangement was proved through test-application of over 75,000 severe individual roller and bearing impacts. Normal operation imposes loads of 600 pounds at 1.5 G's vertical acceleration.

Pullman-Standard also uses McGILL sealed GUIDEROL bearings in their P-S Compartmentizers, wnich consist of two pairs of strong steel gates dividing the box car interior into three flexible-size compartments. The gates roll smoothly on GUIDEROL bearing equipped rollers for easy, quick, one-man operation.



OLIVER tractors use GUIDEROL® bearings to provide long life

The Oliver Corporation employs a McGILL GUIDEROL bearing as the rear support for the power take-off shaft of its 660, 770 and 880 model tractors. The application is unusually demanding because of high fluctuating loads which may be applied by universal joints employed at an excessive angle, or by vee-belt or chain sprocket accessory drives. Oliver says the McGILL GUIDEROL has "long life, requires little maintenance, and will accept great loads." It operates at 540 rpm at a theoretical loading of 366 lbs. — greatly magnified by varying PTO attachments.

engineered electrical products

McGILL®

precision needle roller bearings

Send for free copy of McGILL Bearing Catalog No. 52-A.

MULTIROL-GUIDEROL-CAMROL-CAGEROL

McGILL MANUFACTURING CO., INC., Bearing Division
201 N. Lafayette St., Valparaiso, Indiana

Gasket engineering

INTERNAL PRESSURE vs. EFFECTIVE SEALING

Internal pressure creates two forces which can cause leakage in a gasketed joint. Proper flange design and correct selection of gasket materials can overcome these forces.

E. M. SMOLEY,
Research Physicist
Armstrong Research and Development Center

The pressure of confined liquids or gases acts against a gasket in two ways, as shown in figure 1.

1. Hydrostatic end force. This is proportional to the internal pressure and

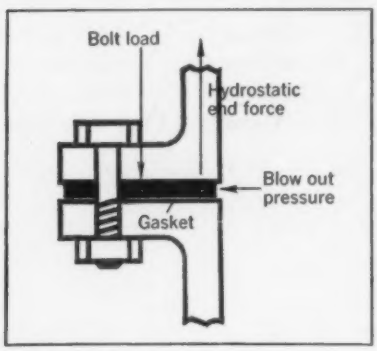


Figure 1. How internal pressure acts on a gasketed joint.

tends to move the flanges apart. As this occurs, the load on the gasket is reduced and leakage can result.

2. Blowout pressure. The sealed liquid or gas exerts direct pressure on

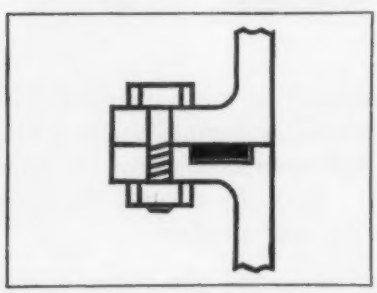


Figure 2. Flange design which confines gasket helps minimize blowout pressure.

the inside perimeter of the gasket. If this pressure is high enough, it will force the gasket out of the joint and leaks will occur.

These forces are usually associated with relatively high internal pressures. Studies at Armstrong Research and Development Center show, however, that pressures substantially less than 100 psi can cause leakage in some assemblies. (The Deflectometer shown in figure 3 is one tool used by Armstrong research engineers to measure flange deflection caused by internal pressure.)

Where internal pressures are involved, it is especially important to consider the joint as a unit. The flange design, the gasket material, and the temperature at the gasket line should all be considered in relation to each other.

The obvious first step is to be sure that flanges are sufficiently rigid to impose the required unit load on the gasket. The number of bolts, their size, their spacing, and their torque values are other factors related to flange loading which must be considered.

The second step is the evaluation of the gasket material to be used. High unit loads dictate the choice of a material that will not extrude or rupture under high pressures. This usually means a dense cellulose fiber or asbestos fiber material.

Several compositions suitable for service under high flange loads are available in the Armstrong Accopac line of beater-saturated gasket materials.

Where a compressible material such as cork-and-rubber is to be used, a flange design which confines the gasket,

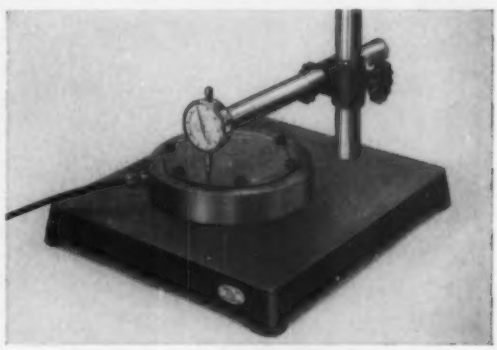


Figure 3. This Armstrong developed Deflectometer measures effect of 70 psi internal pressure in this stamped flange. Leak-producing deflections of .007" were detected at center point between bolts.

as in figure 2, will also help overcome blowout pressure.

A more complete discussion on the effect of internal pressure and other problems of gasket design, selection, and performance is included in the Armstrong Gasket Design Manual. Write today for your copy of this 32-page book. Address Armstrong Cork Company, Industrial Division, 7103 Irvin Street, Lancaster, Pennsylvania.

Armstrong GASKET MATERIALS

Masland Duran CLAD on the
Frigette Auto Air Conditioner by
FRIGIQUIP CORPORATION
Oklahoma City, Oklahoma

Helps speed production . . . and product sales, too

Masland Duran CLAD vinyl finish

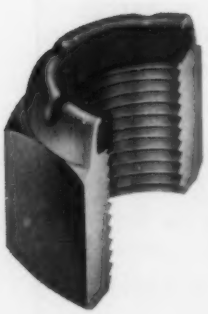
This versatile vinyl can be laminated to metal to provide a built in finish that eliminates dipping, spraying, coating, etc. It can be cut, crimped, drilled and even deep-drawn without impairing its colors or designs. Easy to clean colors. A powerful competitive advantage for *your* product.

Write for information and samples . . . and the name of the laminator in your area.

Industrial Products Division
THE MASLAND DURALEATHER COMPANY
Dept. PE-C, Amber & Willard Sts., Philadelphia 34, Pa.

When frequent adjustment or dis-assembly is anticipated

USE NYLON INSERT ELASTIC STOP® NUTS



Extended re-useability is built into every standard Elastic Stop nut. The tough nylon locking collar does the trick.

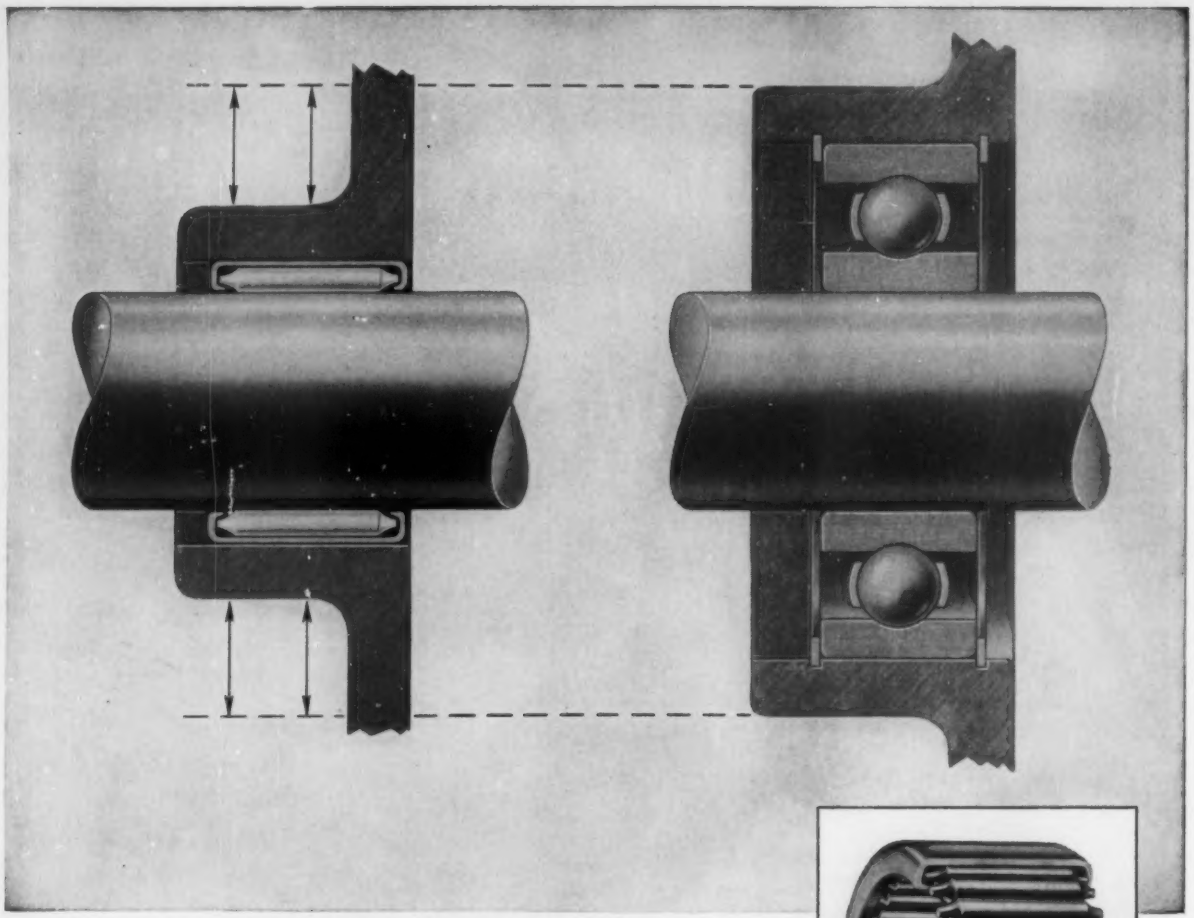
It grips entering bolt threads with a plastic-smooth perfect fit that dampens impact loads, absolutely resists vibration, yet never galls or damages bolt threads. The nut may be "stopped" at any place on the bolt, whether seated or not, for precision adjustment. When the nut is wrenched off for routine maintenance, the nylon collar, due to its elastic recovery, tends to resume its original shape. Thus upon re-installation it grips the bolt threads as effectively as on the original installation. And this on-off cycle can be repeated over 50 times on any bolt of standard quality without loss of holding power.

The nylon locking collar can also be used to seal off liquid seepage along the bolt threads and to prevent moisture from entering the load carrying areas. It is inert to oils, gasolines, salt atmospheres and common acids.

Consider the economy to you and your customers of this kind of fastener performance. Let us prove it to you. Ask for free test samples . . . or a copy of Recommended Test Procedures for Determining Locknut Re-Useability. Write: Elastic Stop Nut Corporation of America, Dept. S50-345, 2330 Vauxhall Road, Union, N.J.

for the ring of reliability

ELASTIC STOP NUT CORPORATION OF AMERICA

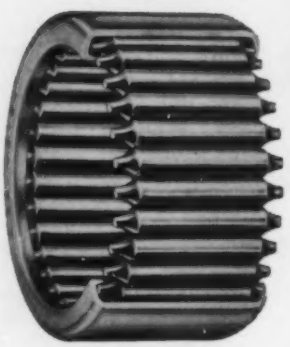


Designed for Compactness... Torrington Needle Bearings

Simpler, more compact design is possible wherever Torrington Needle Bearings are put to work in eliminating friction problems.

These outstanding bearings offer a higher radial load capacity than any other bearing of comparable size. They are more compact, lighter in weight, and are lower in unit cost. The full complement of small-diameter precision rollers insures exceptional antifriction performance and long, maintenance-free service life. The turned-in lips on the outer shell guarantee positive roller retention. Installation and assembly are fast, simple, economical.

The unmatched design and production advantages of Torrington Needle Bearings have been proved in applications ranging from office machines to automobiles, washing machines to earth-moving machinery. Give *your* product the benefit of our antifriction know-how. Write or call Torrington—maker of every basic type of antifriction bearing.

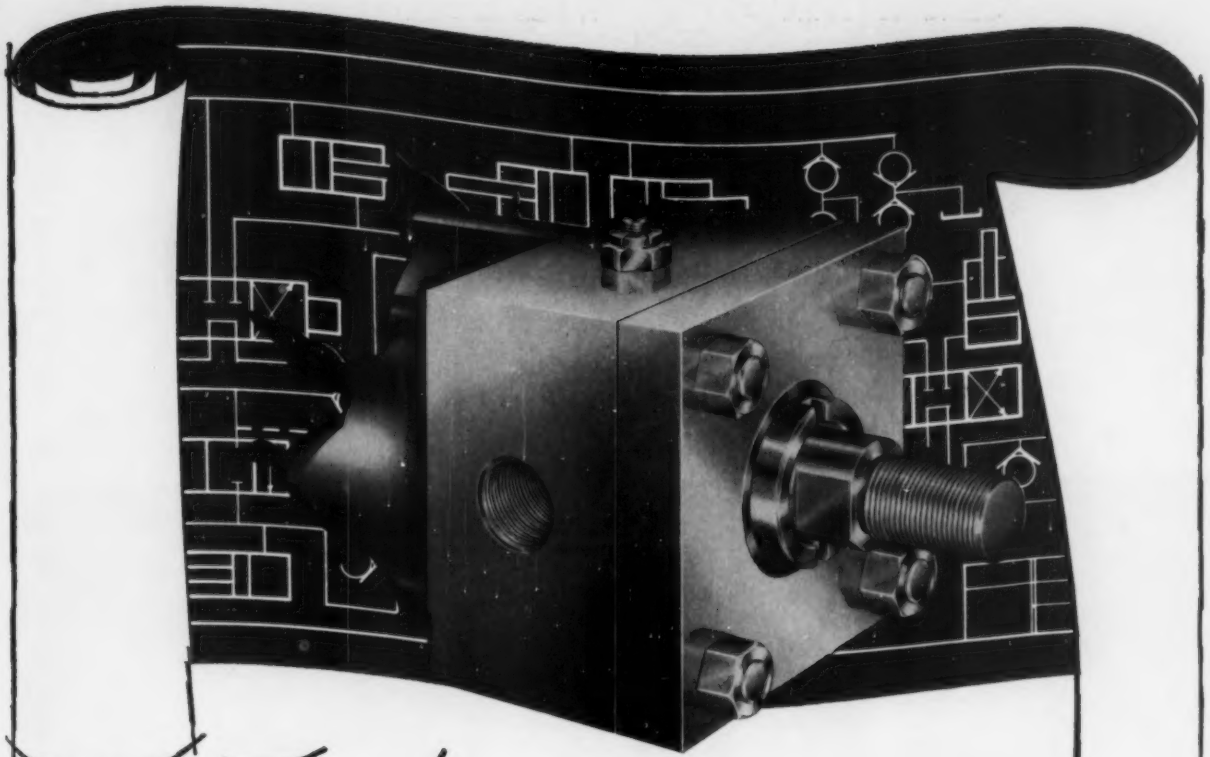


TORRINGTON NEEDLE BEARINGS FEATURE:

- Full complement of retained rollers
- Unequalled radial load capacity
- Low coefficient of starting and running friction
- Low unit cost
- Long service life
- Compactness and light weight
- Run directly on hardened shafts
- Permit use of larger and stiffer shafts

progress through precision **TORRINGTON BEARINGS**

THE TORRINGTON COMPANY Torrington, Conn. • South Bend 21, Indiana



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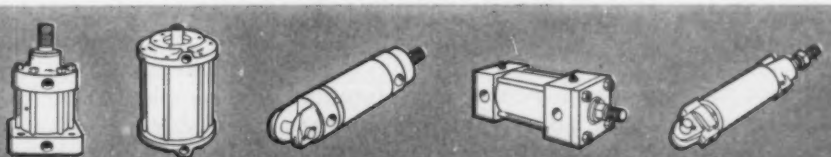
From its blueprint stage to its maintenance engineering requirement sheet, your product will assure MORE power drive precision and service, if T-J cylinders are specified. T-J's complete line too, from the Spacemaker to the new replaceable Squair Head, can be the answer to any power problem. Write or call The Tomkins-Johnson Company, 2425 W. Michigan Ave., Jackson, Michigan, today!

T-J OFFERS THE ONLY COMPLETE CYLINDER LINE



STANDARD HYDRAULIC | STANDARD PNEUMATIC | AIR and HYDRAULIC SPACEMAKER | AIR and HYDRAULIC SQUAIR HEAD | HIGH PRESSURE SPACEMAKER

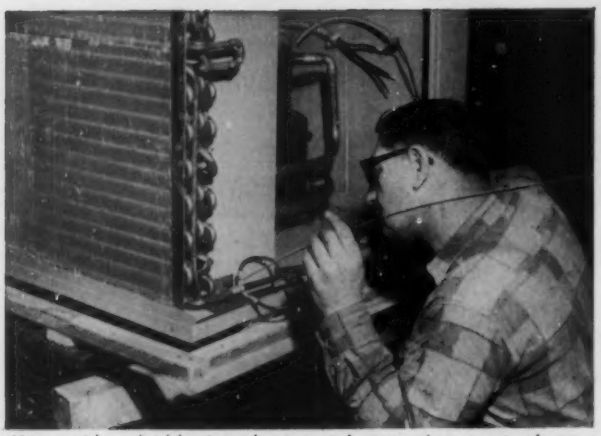
PLUS complete catalog service

T-J **TOMKINS-JOHNSON**

RIVITORS...AIR AND HYDRAULIC CYLINDERS...CUTTERS...CLINCHORS

Representation in all major areas, including Canada.

HOW TO MAKE 4,999 JOINTS WITHOUT FAIL



Here, with a double tipped oxyacetylene torch, operator brazes condenser coil joints. This condenser-compressor assembly contains 30 hook-up joints, not counting return bends.

The unit evaporator, located inside the house, contains 36 hand-brazed SIL-FOS 5 joints.

International Heater Does it With HANDY & HARMAN SIL-FOS 5

Production statistics of this manufacturer of heating and air-conditioning equipment show that perhaps one in five thousand hand-brazed joints may need touching up. This is a micrometer measurement away from absolute perfection.

One of the Utica, New York, company's products is a home air conditioner that utilizes the existing duct work of the structure's hot-air furnace. Its novelty lies in the fact that the unit's compressor and condenser are located outside the house for noise-free coolness inside the home.

The unit's evaporator is installed on top of the furnace for simple tie-in to the plant's ducting for hot-weather operation.

Shown here in production is International's Model 5-5B of 5 ton capacity.

This "joint in quantity" record is being duplicated by SIL-FOS 5 silver alloy brazing in the manufacture of heating, air-conditioning and refrigeration equipment everywhere. Its strength, air- and leak-tightness and ease of application are some of the reasons that make Handy & Harman SIL-FOS 5 brazing one of the *surest* metal joiners in existence. We'd like you to know more about SIL-FOS 5 and the job it can do for you in joining copper and copper alloys in any shape, size and complexity. Our Bulletin 20 deals with this in a complete and informative manner. A request to Handy & Harman, 82 Fulton Street, New York City 38 will bring you your copy.

Your No. 1 Source of Supply and Authority on Brazing Alloys

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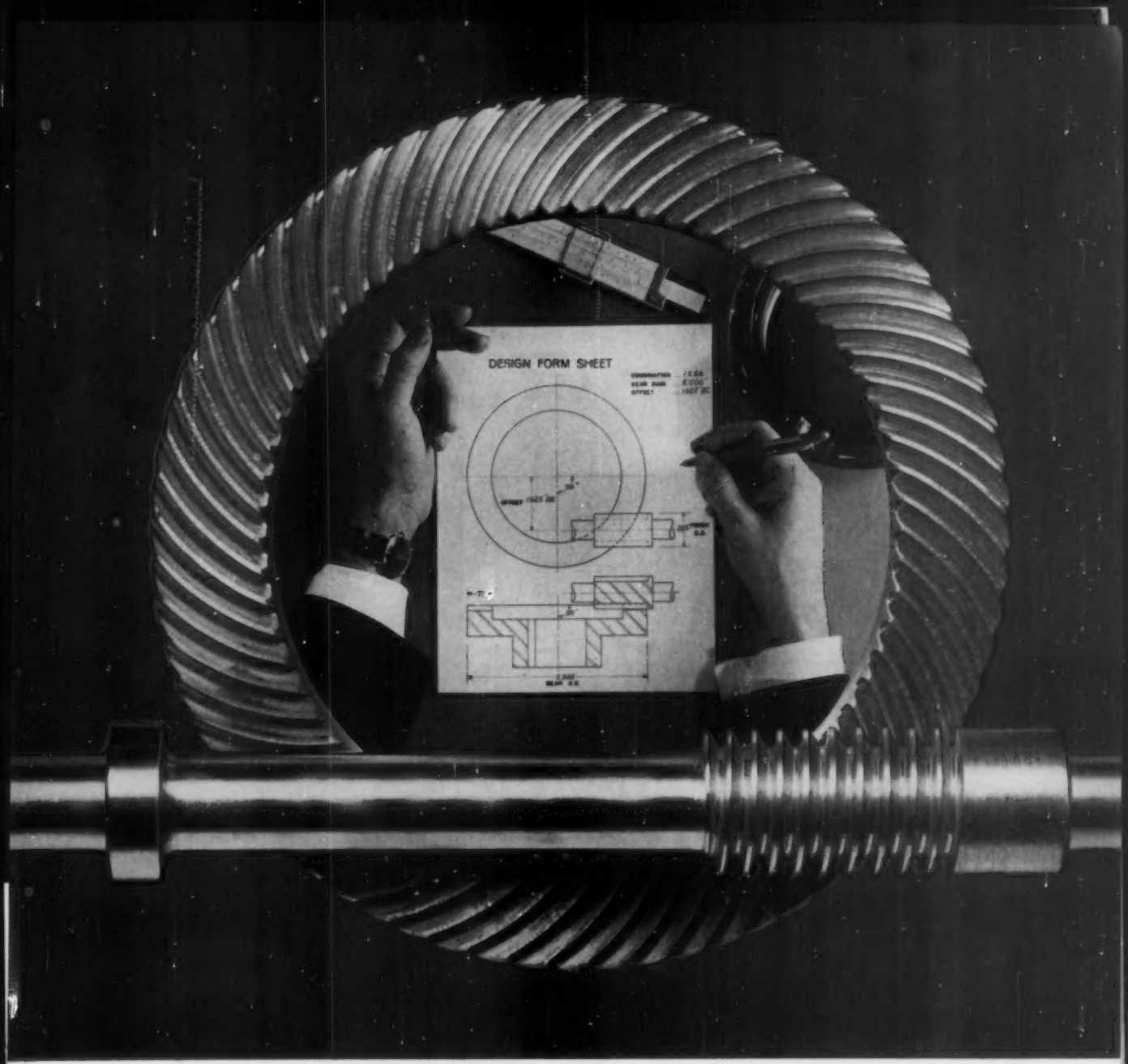

Why it will pay to design your high reduction gearing with Gleason HRH*

If you want to make your transmission more quiet or more compact or more flexible, take a good long look at the HRH set shown above.

This single set of gears gives a reduction of 66 to 1.

The action is quiet and smooth and continuous because the pinion teeth *wrap around* the gear teeth. With this design you can work such quiet operation into your designs even with a one- or two-tooth pinion member.

You can add the rigid support of a straddle mounting, since bearings can be put on both ends of the pinion.

HRH gear ratios are made with proven face mill cutting techniques, assuring complete control of tooth contact pattern to compensate for any assembly or operating condition.

HRH gear ratios are designed with the *full* assistance of all Gleason engineering services. We work with you on the practical design aspects and carry through to the development of prototypes. Then we furnish both machines and tooling for full production—*without royalties.*

Find out what HRH gearing can do for your transmissions. Send for our design form sheet and then send us the gear ratios and sizes you want. We'll send back detailed recommendations promptly.

*Trademark for Gleason High Reduction Hypoids

GLEASON WORKS

1000 UNIVERSITY AVE., ROCHESTER 3, N.Y.

CIRCLE 49 ON READER SERVICE CARD

More OEM's than ever before are swinging to FORD POWER ...because

1 ALL FORD INDUSTRIAL ENGINES ARE COMPACT OHV DESIGN

2 FORD INDUSTRIAL ENGINES DELIVER MORE HORSEPOWER

3 FORD INDUSTRIAL ENGINE SERVICE IS AVAILABLE EVERYWHERE

These are just a *few* of the many reasons original equipment manufacturers from coast to coast are specifying Ford Industrial Engines.

Only Ford offers a *full line* of modern, overhead-valve-design engines. They're compact and modern, delivering *more horsepower per pound of engine weight than ever before possible.* For OEM design engineers, this means greater freedom of equipment design plus important weight savings!

For *true* economy, Ford's short stroke design can't be matched . . . it minimizes friction and delivers more *usable* power from every drop of fuel! And overhead valves permit faster, easier servicing. Costly downtime is further pared for your customers by the immediate availability of parts and service. *All* the more commonly purchased replacement parts are stocked by your nearest Ford Dealer.

Ford Industrial Engines range from 134 to 534 cubic inches, including modern diesels. Most engines are available as foot- or skid-mounted power units. For dependable power that can be easily matched to your original equipment requirements . . . specify Ford Industrial Engines!

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INDUSTRIAL ENGINES
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YOUR JOB IS WELL-POWERED WHEN IT'S FORD-POWERED!

INDUSTRIAL ENGINE DEPARTMENT, FORD DIVISION, FORD MOTOR CO., P.O. BOX 598, DEARBORN, MICH.

West of Rockies write to:
→ FORD INDUSTRIAL ENGINE DEPT., P.O. BOX 6787, LOS ANGELES 22, CALIF.
→ FORD INDUSTRIAL ENGINE DEPT., P.O. BOX 1666, RICHMOND, CALIF.

CIRCLE 51 ON READER SERVICE CARD→

hoover quality balls

. . . PEARLS OF INDUSTRY

You would look a long time to find a component that does so much for end products, that is made so accurately, yet costs so little as a ball. Of course, the rounder and smoother it is, the better the ball does its job.

In Hoover *Micro-Velvet* balls, made of the finest chrome alloy steel, sphericity is measured in millionths of an inch . . . surface finish is microscopically smooth. Gem-like perfection makes *Micro-Velvet* balls ideal for use in bearings and many other precision products.

Millions of balls are produced each month in Hoover Ball Division plants in Middletown, Ohio and Erwin, Tennessee. In addition to chrome steel, Hoover makes balls of carbon steel, stainless steel, brass, bronze, monel and other metals in sizes from 1/16" to 4½" for a wide range of industrial applications. Specialized manufacturing techniques and exceptional quality control methods maintain high *Hoover Quality* standards.

Micro-Velvet and *Hoover Honed* are Hoover Trademarks.

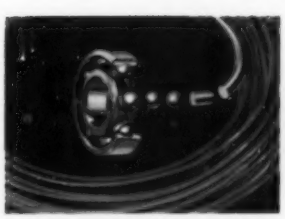
hoover

BALL DIVISION

P.O. Box 381, Middletown, Ohio

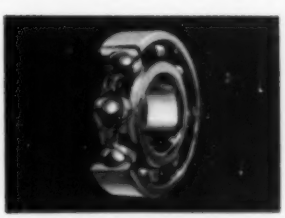
hoover ball and bearing company

hoover CONTROLS *hoover quality* FROM START TO FINISH

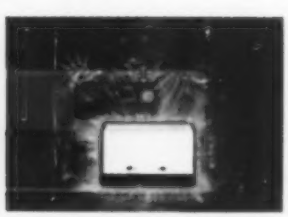


High quality wire from which balls are made is produced by Hoover's Cuyahoga Steel and Wire Division.

It's easier to strike a match on plate glass than on the smooth finish of a *Hoover Honed* bearing raceway.

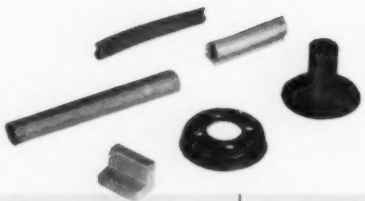


Micro-Velvet balls are used in precision bearings produced by Hoover and other leading bearing makers.



Hoover quality control methods include non-destructive electronic inspection of bearing components.

RUBBER in Design Engineering



Garlock offers dozens of different types of rubber, each carefully chosen and processed to meet your exacting needs . . . natural rubber with high tensile strength where real "rubber-like" properties are required . . . styrene butadiene rubber, the work horse of the industry—a low cost material for use where a good, rugged general purpose compound is required . . . neoprene rubber where good oil and abrasion resistance and aging characteristics are important. In addition, Garlock offers a wide range of nitrile and butyl compounds where their special properties are required. For more difficult applications Garlock offers a complete line of specialty rubbers from silicone for high and low temperature service to VITON* for extreme temperature and solvent resistance.

PROPERTIES	Non-Oil Resistant			Oil Resistant	
	Natural	SBR	Butyl	Nitrile	Neoprene
Tear Resistance	Excellent	Poor-fair	Good	Fair	Good
Abrasion Resistance	Excellent	Good	Good	Excellent	Excellent
Compression Set Resistance	Good	Good	Good	Very good	Good
Permeability to Gases	Fair	Fair	Excellent	Very good	Very good
Aging (Sunlight)	Poor	Poor	Excellent	Fair	Excellent
Aging (Oxidation)	Good	Good	Good	Fair	Good
Aging (Heat, max. temp. F)	200	250	300	250	250
Solvent Resistance (Aliphatic Hydrocarbons)	Very poor	Very poor	Poor	Good-Exc.	Fair
(Aromatic Hydrocarbons)	Very poor	Very poor	Poor	Fair-good	Poor
Oil Resistance (Low Aniline)	Very poor	Very poor	Very poor	Fair-Exc.	Fair
Oil Resistance (High Aniline)	Very poor	Very poor	Very poor	Fair-Exc.	Good
Gasoline Resistance (Aromatic)	Very poor	Very poor	Very poor	Fair-good	Fair
Gasoline Resistance (Non-aromatic)	Very poor	Very poor	Very poor	Good-Exc.	Good
Cold Resistance (Min. svc temp. F)	—65	—70	—65	—65	—50

This table gives you an idea of how some rubbers react to various conditions. In designing, consult your Garlock rubber specialist to achieve best application results.

Thoroughly tested to meet ASTM standards. Over twenty various tests are conducted on rubber materials before, during, and after manufacture to assure top performance. First, the rubber is carefully compounded and mixed exactly to specification. Then it is measured for durometer hardness, tensile strength, elongation . . . resistance to water, weather, temperature . . . many other vital characteristics. Scientific measurements like this, using ASTM, SAE-ASTM, and military standards—plus quality control during manufacture—assure you of the finest rubber parts available.

No two rubbers are alike. Each has its own individual strong points; each performs better under one set of conditions than another. In the design stage, call in your Garlock representative. He's a specialist in rubber parts and will assist you in selecting the proper material. Then, too, he may have several cost-saving ideas to suggest. You

GARLOCK

can reach him at the nearest of the 26 Garlock sales offices and warehouses throughout the U. S. and Canada. Or, write for Catalog AD-167, Garlock Inc., Palmyra, N. Y.

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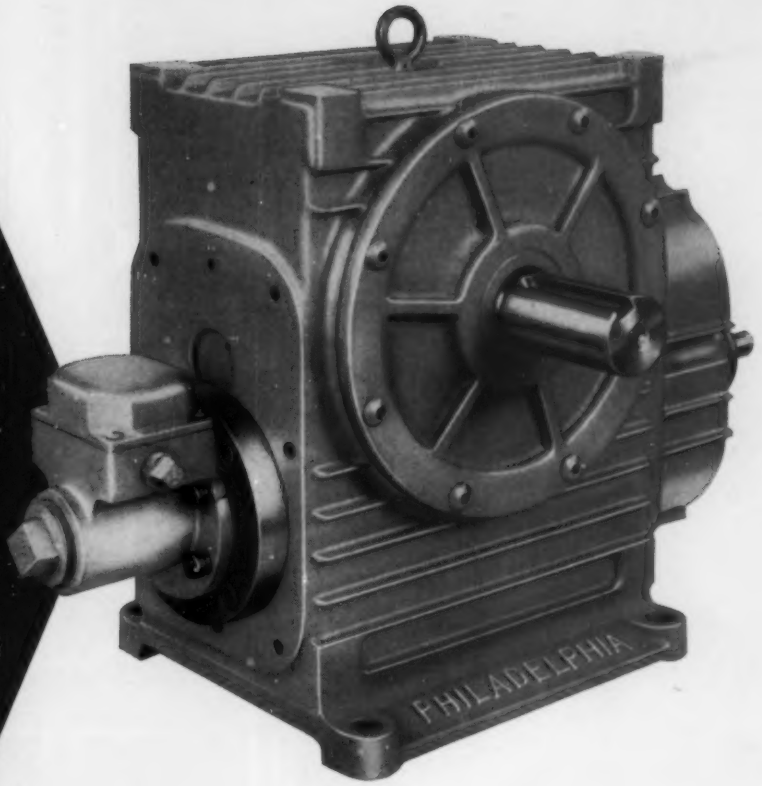
Order from the Garlock 2,000 . . . . two thousand different styles of Packings, Gaskets, Seals, Molded and Extruded Rubber, Plastic Products.

*Du Pont Trademark

INSIDE!

AN AUTOMATIC SWITCH FOR FAST, SURE PROTECTION AGAINST OVERLOAD

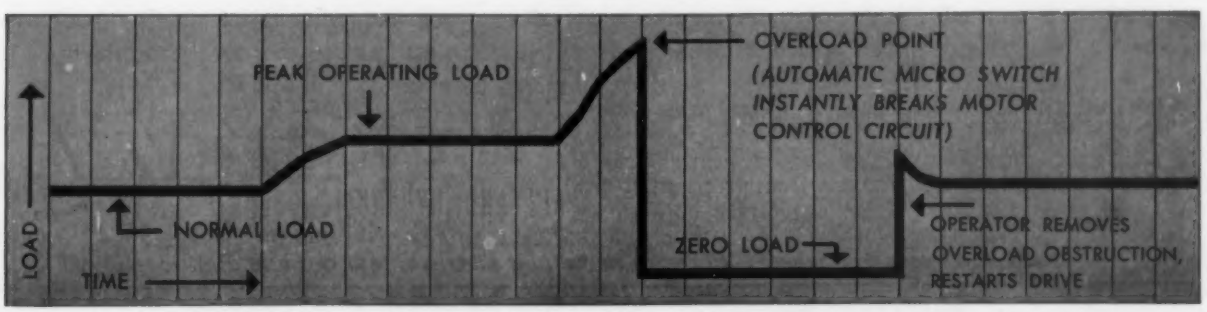


Here is instant protection against overload damage . . . Philadelphia Gear's Torque Control for worm gear reducers. When output torque of the reducer exceeds a pre-set value, the control breaks the motor control circuit—instantly. This is accomplished by mechanical actuation of an electrical line break switch. Truly foolproof protection for driving and driven equipment.

Time saved with Torque Control can be considerable, too. For example, you can remove the cause of overload or jam immediately. There is no waiting for heaters to function or for shear pin replacement. In short, downtime is either drastically cut or eliminated.

How about starting surge? Here, too, is an advantage . . . the control can be by-passed by holding the START push button to permit this temporary overload. Torque Control is optional on Phillie Gear equipment, and is available for either one direction of operation or both.

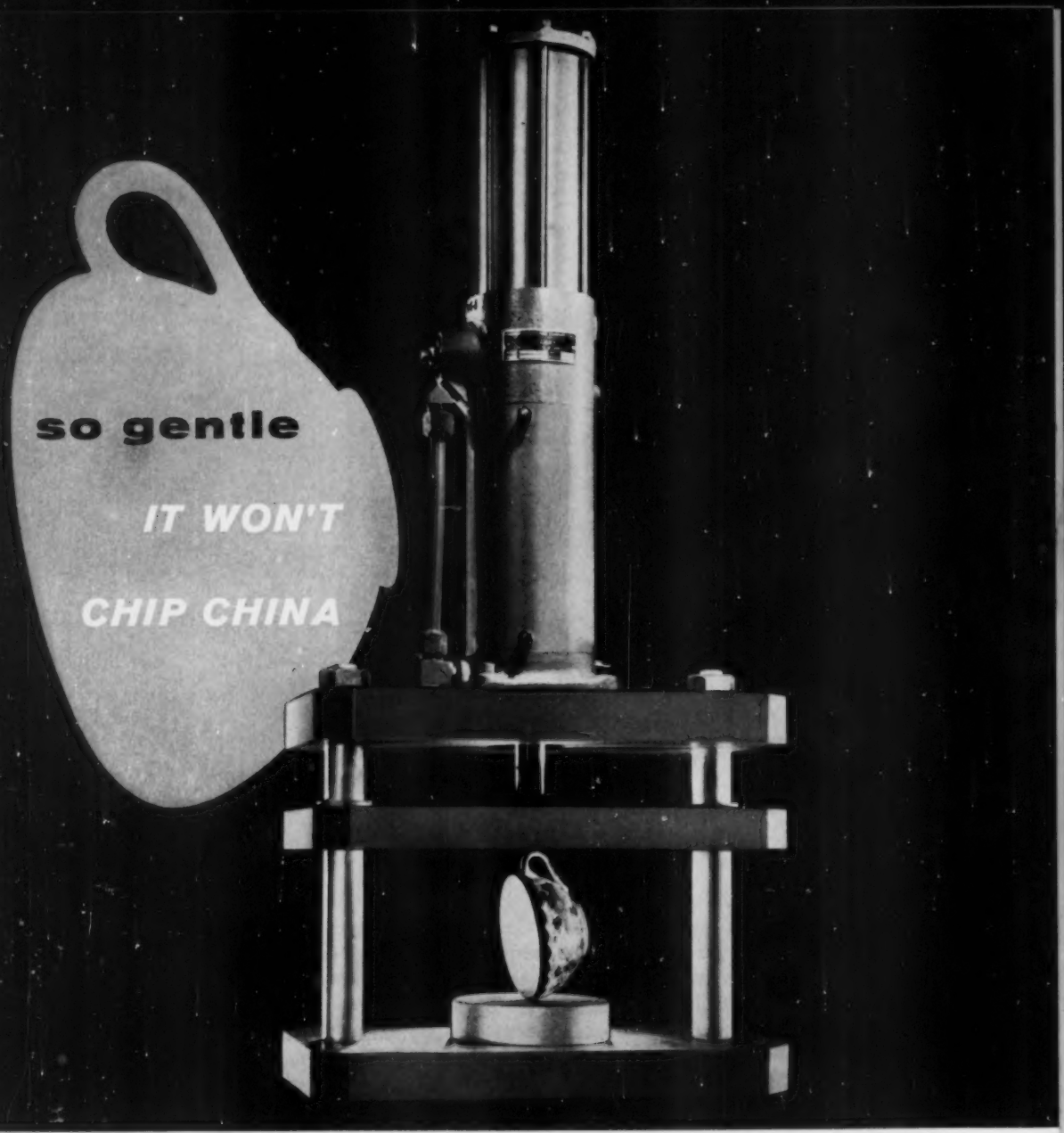
For information on our complete line of Worm Gear Reducers, write for catalog WG-60.



philadelphia gear drives

PHILADELPHIA GEAR CORPORATION

King of Prussia (Suburban Philadelphia), Pennsylvania



So gentle it won't chip china, yet powerful enough to bend steel tubing as if it were a soda straw. In a nutshell, this demonstrates the almost unbelievable degree of control built into Logan air-draulic devices.

The controlled accuracy gives this equipment a versatility and flexibility that makes it adaptable to all kinds of jobs, ranging from precision laboratory assignments to actual production line work.

If you would like additional information about air-draulic devices or other Logan products, merely fill in the coupon below.

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PRODUCT ENGINEERING HORIZONS

March 20, 1961

3-D Testing

"When a satellite, or one of its sub-assemblies, fails there's just nothing to do about it. We haven't got a screwdriver long enough to get at it." Thus the research director of one large missile contractor summarized his current problems. "We're doing research, development, design and production all at the same time. Our product is supposed to last a year in orbit, but there isn't time or money enough to run the necessary life tests, so we have to design for a lightweight one-hoss shay—something that will presumably operate almost indefinitely.

"Add to that the fact that we cannot reproduce, on earth, the actual conditions existing in space, and you begin to get some idea of why our reliability requirements are the toughest in this world—or really, out of it. Epoxies, our finest adhesives, sublimate in vacuum as a result of vapor pressure, so they hold nothing. The 10^{-10}-mm Hg vacuum creates lubrication problems—lubricant simply leaves the bearings. Radiation effects are many and various; some materials lose temper, others become brittle, others break down. Remove gravity and wet batteries won't work; the gas bubbles stay on the plates. Lack of gravity similarly affects all sorts of other elements designed by men who automatically expect gravity to have its effects.

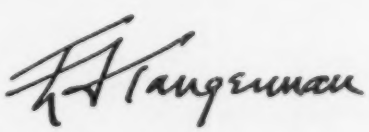
"We must write new design handbooks—for space. The familiar values have no meaning, the 'drawing' in the classical sense doesn't fit. We need a new language and a new approach."

Other men are not so eloquent, but they can be found altering traditional approaches. Perhaps the most noticable changes are in testing. It isn't practical simply to test by normal means. Every test must be pre-evaluated to be sure all environments are considered, that maximum value is obtained from every test. The standard procedure of varying one environment while other are held constant, assuming that such individualized results can be summed up later, is no good either. Failure after failure has occurred through *combinations* of environments, all varying at the same time. One missile design failed from combined bending and torsional stresses, another through dirt and damage during fueling, and so on.

The result of all these problems is multi-environment testing—varying several environments simultaneously. Vibration and temperature swings are applied together with loading. Every component maker is doing some of it now, and prime contractors are doing a lot. It even has a special slang name: "3-D testing." It is saving endless launching-pad problems.

Our reason for mentioning it here is that it may apply to your product as well. How many failures have you had because a user ran into a condition for which you hadn't tested? Or a combination of conditions that cause trouble that no one condition would?

With designs trending toward lighter-weight, more-heavily stressed components, much more elaborate engineering, and much more complexity, better testing is essential. And even if your product is a missile or a satellite, the emphasis these days is on cost as related to performance—on reliability, quality, integrity or old-fashioned value.



←CIRCLE 54 ON READER SERVICE CARD

Zero burnout time
and minimum "haloing"
are combined in CDF's new grade 614 glass fabric epoxy laminate at no increase in price over conventional NEMA G-10 grades. Available plain or copper-clad, 614 is a cold punch material that is also superior in flame retardancy, has excellent trichloroethylene vapor resistance and low moisture absorption. The grade is distinguished by its opacity and its tan color.

Result: Another example of CDF leadership in meeting critical military and industrial applications while effecting important customer savings!

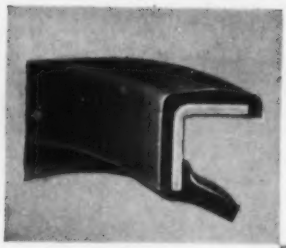
Typical properties of 614 (1/16" thickness):

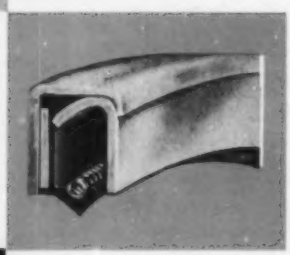
Burnout Time, sec.	0
Water Absorption	0.10
Flexural strength, psi, lw	75,000

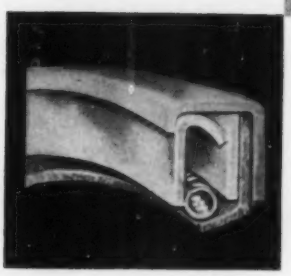
(Copper-clad 614 meets MIL-P-13949B, Type GF Plain meets NEMA G-10; approval pending for MIL-P-18177B, Type GEE. Also pending under NEMA proposed FR-4)

CDF CONTINENTAL-DIAMOND FIBRE

CONTINENTAL-DIAMOND FIBRE CORPORATION, NEWARK, DELAWARE • A SUBSIDIARY OF THE Bird COMPANY







PRODUCT ENGINEERING

special report

HOW TO CHOOSE A DYNAMIC SEAL

V L PEICKII, *director of research & engineering*
DAN A CHRISTENSEN, *research engineer*
National Seal Division
Federal-Mogul-Bower Bearings Inc,
Redwood City, Calif

What is the true function of a seal? It may be used to:

1. Seal-in oil, grease or other fluid
2. Seal-out dirt, fluids and contaminants
3. Maintain applied pressure or vacuum
4. Or perform a combination of these jobs

But a seal will have to do more. Each application imposes its own special problem.

SEALING IN

- What about oil surge pressures?
- What are the leakage tolerances (in and out)?
- Do adjacent bearings, gears, etc., keep the lubricant away from the seal; or do they create local high-pressure areas or jet streams against the seal?
- Is the housing vented to relieve pressure caused by raised temperature?

SEALING OUT

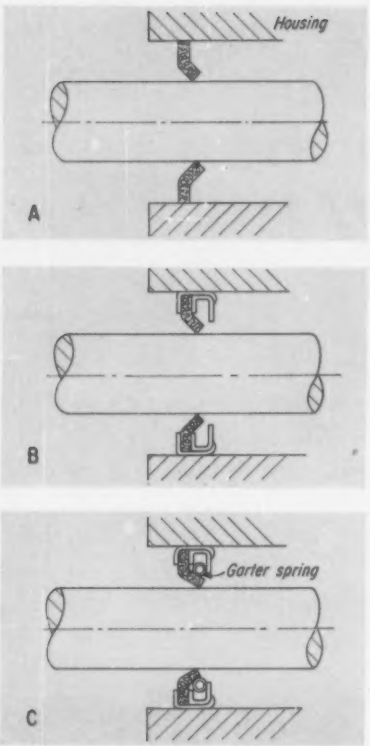
- Does the housing allow dirt to pack against the seal?
- When the assembly cools, is it vented to prevent contaminants being sucked in by the created vacuum?
- Is the seal protected against direct splash?

PRESSURE OR VACUUM

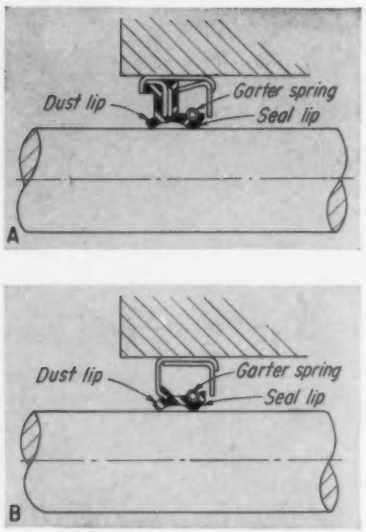
- Are static conditions better, same, or worse than operating conditions?
- Is there alternating vacuum and pressure caused by operating conditions or between static and dynamic conditions?

The designer has 5 basic types of seals to serve him. He has 17 materials to choose among. He has hundreds of design configurations. Beginning on next page is a complete review of all the types and an exhaustive analysis of each in terms of basic selection factors, materials, and design recommendations.

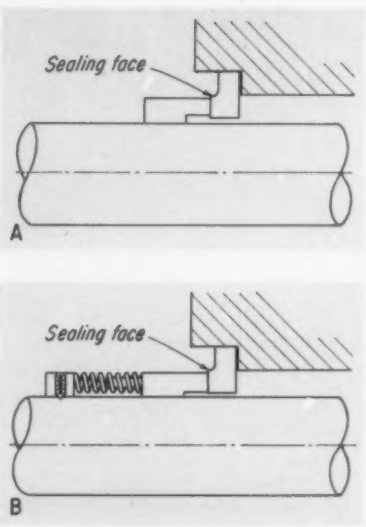
REPRINTED—Circle 594, inside back cover



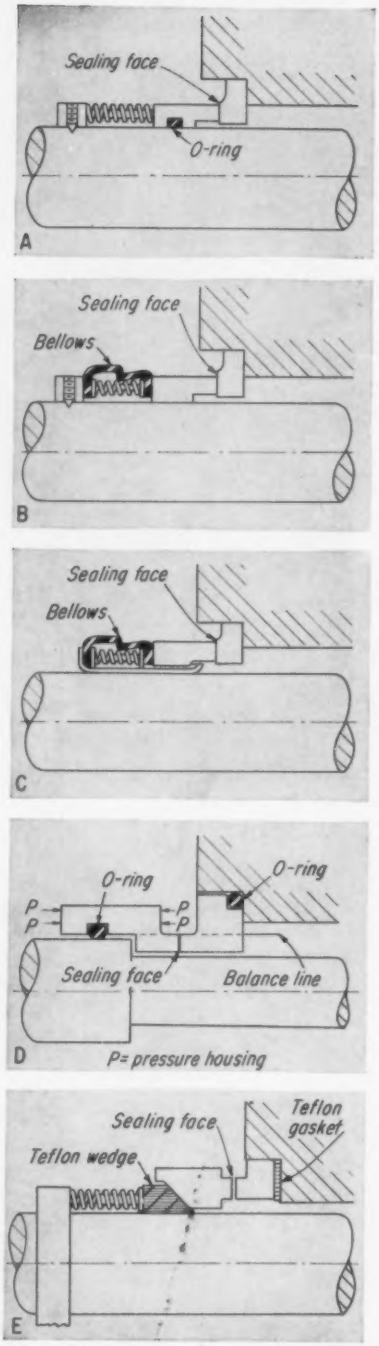
1 . . . BASIC SHAFT SEAL (A) has leather or rubber lip attached to housing and held against shaft. Steel case (B) facilitates mounting, and garter spring (C) holds lip against the shaft.



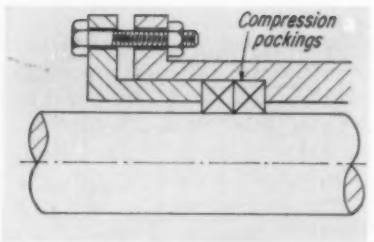
2 . . . TO EXCLUDE DUST and other contaminants from shaft seal, a dust lip is added. It can be a separate element (A), or integral (B).



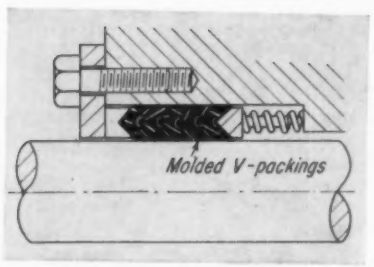
3 . . . BASIC FACE SEAL (A) has two flat radial faces—one connected to the housing, the other to the shaft. Spring force, as in (B), is usual means of holding the faces together to take up wear and axial movement.



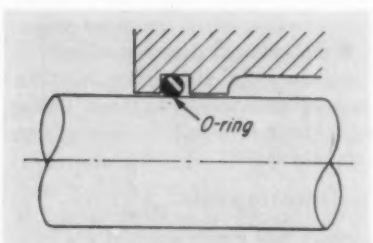
4 . . . AUXILIARY SEALING with face seal is performed by an O-ring (A) or bellows (B). To counteract shaft torque, bellows type can be mounted in a metal case with torque locks (C). Where internal pressures are high, pressure-balanced faces must be provided as in (D). For high temperatures a Teflon wedge (E) compensates for expansion.



5 . . . COMPRESSION PACKINGS consist of twisted, woven or braided strands of vegetable fibers, asbestos or soft metals.



6 . . . MOLDED PACKINGS are usually made in U or V shapes and assembled in multiples with a spring-loaded take-up for wear.



7 . . . SPECIAL FORM of molded packings is the O-ring (also made in cross-sectional variations of D or square shapes).

THE TYPES OF SEALS

There are five basic types to choose among. The choice depends on many functional, environmental and economic factors. Each type of seal has its own configurations and principles of operation which make it particularly suitable for specific applications.

Shaft seals

A leather or synthetic-rubber flange or lip attached to the housing and held against the shaft, Fig 1(A), is the basic sealing element. A metal case usually holds this element in position Fig 1(B).

Misalignment, shaft runout, seal shrinkage, surge pressures and other cyclical factors tend to lift the lip off the shaft either intermittently or continuously. Consequently, a finger or garter spring is added to hold it against the shaft, Fig 1(C).

A dust lip is often added to exclude dirt and other contaminants. It can be a separate element, Fig 2(A), or molded integrally, Fig 2(B), with the primary rubber sealing lip—with either or both lips bonded to a washer or to the case. This produces rigidity, permits accurate positioning, and represents the basic shaft seal design.

Primary characteristics of this seal are: small space requirements; wide variety of standard sizes, materials and lip combinations; good sealing with many types of fluids; and good exclusion of dirt or contaminants.

Face seals

Sealing is performed by continuous contact between two smooth, essentially flat radial faces—one attached to the shaft and the other to the housing, Fig 3(A). One face is designed to move axially to take up wear or play, usually by means of a spring, Fig 3(B). The rotating face must seal to the shaft as with an O-ring, Fig 4(A), or a rubber bellows, 4(B).

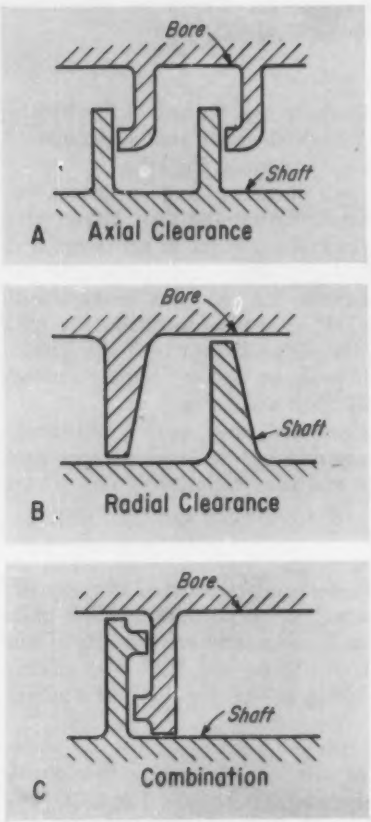
To counteract torque between shaft and sealing face, the seal assembly is often mounted in a metal case with integral torque locks and with gasketing, or press-fit between the shaft and the case, Fig 4(C). The seal assembly can be made either internal or external, and rotating or nonrotating. Other variations of face-type seals are the pressure-balanced type, Fig 4(D), where face pressure is independent of housing pressure; and the high-temperature seal, Fig 4(E), in which a Teflon wedge compensates for axial play and runout. O-rings or similar sliding seals can serve instead of Teflon. In high temperatures or other rubber-degrading atmospheres, metal bellows are sometimes used.

Face seals are most useful where high pressure, temperature, speed or contaminating conditions exist. They are usually specially designed for pumps, process machinery, high-speed and high-temperature motors, earthmoving equipment and military vehicles. However, simple, inexpensive designs are commonly used on automotive water pumps and similar applications.

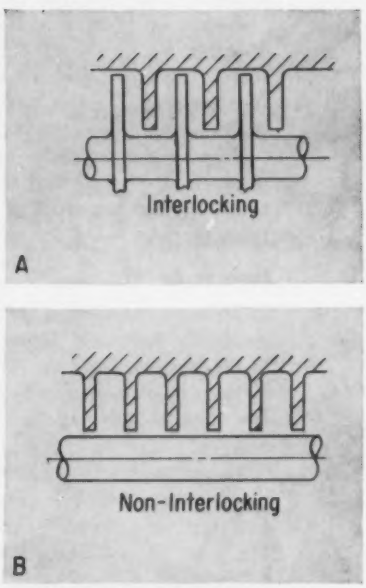
Compression packing

The oldest type of seal still widely used consists of twisted, woven or braided strands of vegetable fibers, asbestos, or soft metals packed between shaft and housing. These are often combined with a binder and a lubricant. In practice, the packing is usually placed in one or more coils in a bore and compressed with a flanged unit (Fig 5).

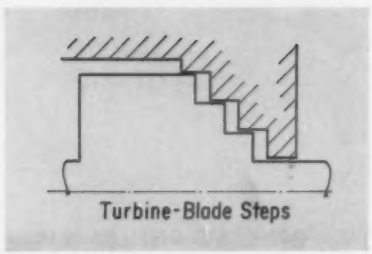
Compression packing is used at relatively low speed, and in high-pressure and temperature applications where occasional leakage is



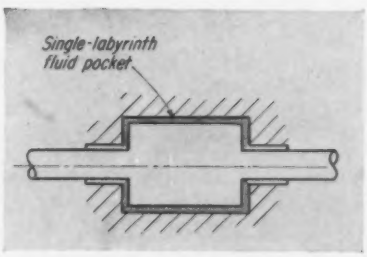
8 . . . LABYRINTH or positive clearance seals limit leakage by means of abrupt cross-sectional changes with axial clearance (A), radial clearance (B) or a combination (C).



9 . . . LABYRINTH SEALS are also classified as interlocking (A) or non-interlocking (B).



10 . . . STEPPED LABYRINTH is a variation of the interlocking type.



11 . . . SINGLE LABYRINTH uses a dense fluid to seal gas or light fluids.

tolerable. This type has been supplanted in many applications, but is still used on pumps, valves, and pistons to seal hot water, steam and other very hot fluids.

Molded packings

Here the loose packing is molded so that it assumes a precise cross-sectional form. The elements can be used individually, or in multiples with a spring-loaded takeup for wear. The usual cross-sectional designs are of the U- or V-type (Fig 6). A special form of the molded packing is the O-ring (Fig 7)—sometimes made with cross-sectional variations in the form of a D or square.

The inherent characteristic of most molded packings is that increasing pressure tends to increase sealing pressure. This is one reason for their popularity in high-pressure and high-temperature piston applications. Another reason: moderate degradation of the material does not affect performance as much as in some other types of seals. They are also often used in combination rotating and sliding applications of relatively slow speed, and the O-ring type frequently serves as a static seal.

Labyrinth or positive-clearance seals

Where no other type will perform satisfactorily, a labyrinth seal can be designed to limit the leakage to a predetermined amount. Such custom-designed seals are called on where conditions of temperature, surface speed and pressure prevent the use of positive-contact seals. They usually have built-in provision to bleed off the leakage.

All labyrinth seals limit the leakage flow by means of

abrupt changes in cross-section. The positive clearance in these seals is of two basic types Fig 8(A and B) or a combination (C). Axial clearance is used where close radial clearance is impossible because of excessive shaft runout or radial expansion. Radial clearance is preferred for applications that require excessive end-play or axial movement. In certain applications a combination of axial and radial clearance labyrinths is possible—this makes them twice as effective.

Another way of classifying labyrinth seals (Fig 9) is according to whether they are interlocking (A), or non-interlocking (B). The interlocking type is more effective, but is also more difficult to assemble.

A variation of the interlocking labyrinth is the step labyrinth (Fig 10) used in single-flow-stream turbines. Here, the reactive end-thrust counteracts the turbine blade end-thrust, and ordinary labyrinth sealing is compounded with centrifugal sealing at each of the steps.

Sometimes, when a sealing fluid denser than the sealed fluid can be used, a single or multiple labyrinth, as in Fig 11, is effective and economical. The dense sealant in such design performs its function by centrifugal action.

SELECTION FACTORS

For a good perspective on each of the basic types, it is useful to summarize the most important selection factors, Table I. Most of the limitations here can be exceeded with special designs or under carefully controlled conditions. But, of course, extremes of all factors cannot be achieved simultaneously by any one type of seal. Evaluations in the table are general and therefore approximate; their usefulness is based on the following definitions and qualifications.

General adaptability indicates how readily the basic type of seal can be adapted to particular applications.

Availability refers to off-the-shelf availability as well as the degree to which standard sizes of each type can be modified to suit special applications.

Positive action evaluations indicate how well each basic type will seal.

Minimum space requirements listed are approximate values for standard small-size seals. Special designs can often be built with smaller cross-sections.

Life estimates are based on average operating conditions of temperature, speed, surface finish and other factors.

Temperature limits are approximate maximum oil-sump temperature, provided other temperature generating conditions are not severe. Life and performance factors can be improved if the design provides for dissipating heat from seal friction. Face seals are often cooled by auxiliary means, particularly in hot-oil pumps; this usually extends their range of usefulness by several hundred degrees. However, there is no advantage in picking a seal to operate, for example, at 400 F if the oil breaks down rapidly at 300 F, because the carbon buildup on the shaft will cause leakage before the seal fails.

Pressure limits are approximate maximum values that will not shorten life of a standard seal excessively. Special designs can often be developed to exceed the listed pressures, but are expensive and must be operated under closely controlled conditions. Applications with high vacuums and minimum pressure-drops are usually sealed best with face seals or molded packings whose relatively large contact area allows good lubrication and minimum leakage. A problem with most shaft seals and some face seals and packings is to guard against reversal of pressure or vacuum—these tend to lift the seal lip or packing, and suck in dirt or other contaminant. Usually, this can be avoided by properly venting the housing to prevent pressure buildup or vacuum caused by temperature changes.

Speed values listed can seldom be exceeded without shortening seal life, unless the design provides for cooling.

Chemical resistance is a general evaluation that indicates what is possible in each basic type. Resistance to specific types of chemicals depends on choice of seal materials (see Table II). It should be noted that trace elements present in oils and fluids can be very destructive to seal materials.

Dirt exclusion varies widely. But in general, shaft seals with auxiliary lips do an excellent job in moderately severe conditions, while face seals are best for extremely dirty conditions, such as earthmoving vehicles. Flushing the grease or oil during periodic lubrication may permit a less costly or otherwise more suitable seal. Protective housing or shroud design is also helpful.

Runout tolerance refers to shaft movement perpendicular to the axis which can be caused by shaft misalignment or eccentricity. When runout tolerance exceeds the limits shown, special seal designs must be developed. In general, all seals perform better and last longer when shaft runout is low—runout at high speed gives dynamic forces that can destroy the seal rapidly. Excessive runout can also cause heavy leakage, even in a newly installed seal. Since packings have little flexibility, they will not tolerate much runout. In labyrinth seals, clearances are too low to allow much runout.

Axial shaft movement is generally a limiting factor only in face seals where axial movement is limited by spring travel. However, high axial acceleration can make any seal leak. In the face seal it causes the sealing faces to separate, and leakage in other contact seals results from the high pressure built up ahead of the contact area, and ineffective wiping. Packings are generally best suited to this condition.

Lubrication in correct amounts is beneficial to any seal: it minimizes friction and acts as a cooling medium. Shaft seals operate more effectively with intermittent or splash lubrication, because of their low contact area and pressure, particularly at low speed and pressures. Leather shaft seals and some leather and fiber packings absorb enough lubricant to operate well with intermittent lubrication.

Cost varies widely and the relative evaluations are intended to indicate which type might be suitable for detailed study of actual costs in any particular application. The simplest seals, such as O-rings and loose packings,

I—COMPARISON OF BASIC TYPES

Selection Factors	Shaft Seal	Face Seal	Compression Packings	Molded Packings	Positive Clearance
General adaptability	Excellent	Good	Limited	Limited	Specialized
Availability	Excellent	Good	Good	Good	Partly or fully integral with machine
Positive action	Excellent	Excellent	Good under limited conditions	Good under limited conditions	No
Space (radial x axial), in.	¼ x ¼	⅜ x ⅝	¼ x ½	¼ x ½ except O-rings: ⅛ x ⅜ long	Variable but usually large except for single loose rings
Life (hours)	2000	3000	1000	1000	Unlimited in labyrinth type, 1000 hr in others
Temperature limits, °F	−65 to +300 (to 350 intermittent)	−65 to +850	No practical lower limit, to +1500	−65 to +500	No practical lower limit; to +2000
Pressure limits, psi (and vacuum)	15—std. design 100—special	1000	10,000 with rotation and reciprocation	3000 with backup rings and rotation and reciprocation	Depends on number of elements and tolerable leakage; usually 1500
Speed (fpm)	3000	15,000	1000 with reciprocation and rotation	1000 with reciprocation and rotation	10,000 with rings, unlimited with labyrinth
Resistance to attack by oils and chemicals	Good	Excellent	Excellent	Good	Excellent
Dirt and exclusion	Excellent under moderate conditions	Excellent under severe conditions	Good	Good	Fair (leakage usually excludes dirt during operation)
Runout tolerance, in.	0.025	0.025	0.0005	0.002	Depends on design; usually .0005
Axial shaft movement	Unlimited	0.075 in. (depends on design)	Unlimited	Unlimited	Wide variation, depending on design
Lubrication	Intermittent	Continuous	Continuous, may be self-lubricated	Continuous	Continuous with loose rings, none with labyrinth
Cost	Moderate	High, with a few exceptions	Low	Low	Moderate to very high

may cost only a few cents, some face and shaft seals go up to $100. Specially designed positive-clearance seals usually cost even more.

SEAL MATERIALS

Materials for the sealing elements of the first four basic types of seals are evaluated in Table II; these are the materials found in the most popular commercial seals now available. Their listed characteristics are generally applicable, but they will necessarily vary from one seal manufacturer to another. For example, silicone material varies widely and its use in shaft seals or molded packings for specific operating conditions should be checked by the seal manufacturer. Similarly, the performance of carbon face-seals is likely to vary widely, because carbon materials are numerous and can be identified only by a proprietary grade designation. Particle sizes, compositions and processing procedures all affect the performance characteristics of carbon face-seals.

Materials for positive-clearance seals are not listed in the table because the choice is not critical for performance by these seals. Generally, their materials are metals compatible with the shaft or the bore to which they are fastened.

EFFECT OF DESIGN VARIATIONS

Shaft seals

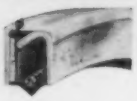
These are used in more dynamic applications than all others combined. This is because of their positive sealing ability; versatility in meeting requirements of temperature, shaft speed and pressure; low cost; relatively high insensi-

text continued, page 65

II—APPLICATION CHARACTERISTICS OF SEAL MATERIALS

	Temperature, °F	Abrasion Resistance	Acceptable Fluids
SHAFT-SEAL MATERIALS			
Nitrile	–30 to 225, continuous. To 300, intermittent	Excellent; R_c 28 or harder and approximately 15-rms shaft recommended	Acid solutions—except strong oxidizing acids; alkali solutions except 10–20% sodium hydroxide; coolants, antifreeze solutions; EP gear oils, all forms; fuels—petroleum, gasoline, diesel fuel; grease—petroleum-base; hydraulic fluids, glycol; lubricating oils; sal solutions; synthetic fluids—polyglycol, silicone and alkyl silicates
Polyacrylic	–30 to 300 Continuous 350 Intermittent	Fair; R_c 28 or harder and approximately 10 rms shaft finish recommended; lubrication must be continuous	Same as for Nitrile
Leather	–50 to 200	Excellent; will operate satisfactorily on 30 rms shaft at slow speeds; best choice for intermittent lubrication	Same as for Nitrile except no aqueous solutions or glycols
Silicone (consult seal manufacturer)	–80 to 500 in air or suitable fluids	Good; R_c 28 or harder and 10 rms shaft finish recommended	Commercial silicone up to 250 F in lube oils. Special silicones in lubricating oils up to 400 F; most industrial chemicals up to 500 F
FACE-SEAL MATERIALS			
Resin (filled, molded, or reinforced)	–60 to 212; lower limit is brittle point of resins; higher limit possible when face-heat generation is low	Excellent in absence of foreign solids when materials are chosen for specific applications	Mineral oils with resins. Hydraulic fluids; synthetic oils, water
Carbon	Up to 500 (usually limited by other seal components)	Excellent with clean fluids	Practically all industrial chemicals and corrosives as well as oils, solvents, water and steam
Ceramic (sometimes bonded to metal)	Up to 500 (usually limited by other seal components)	Excellent; will tolerate high solid contaminants but life will be shortened proportionately	Most industrial chemicals, oils, fuels, and solvents
Metal (steel, stainless, bronze, ni-resist., satellite) Most face seals are available with metallic cases; corrosion and differential thermal expansions must be considered, and corrosion protection applied when necessary	Up to 500 (usually limited by other seal components)	Excellent; governed by material of mating face; when 2 face materials are properly matched, will tolerate contaminating solids and large amounts of external dirt	Oils, fuels, and fluids compatible with corrosion resistance of the metal
Face-seal rubber bellows or boots	32 to 212		Synthetic and mineral oil and hydraulic fluids; most industrial chemicals, water and vegetable acids
Face-seal O-rings and static sealing rings	32 to 212; Kel-F or Teflon up to 500; auxiliary cooling of face seal extends the range		Same as for nitrile above; Teflon and Kel-F are inert to almost all industrial chemicals, corrosives and solvents
MOLDED PACKING MATERIALS			
Nitrile (including fiber-reinforced)	–30 to 225, continuous; to 300 intermittent	Excellent; R_c 45 and 10 rms shaft finish recommended; continuous lubrication required	Same as for Nitrile in shaft seals
Polyacrylic	–30 to 350; consult mfr. on fluids and speeds when nearing these temperatures	Good; must have continuous lubrication	Same as for Nitrile
Silicone	Poor with hot lubricants	Poor	Seal manufacturer should be consulted before using
Neoprene	–65 to 225	Excellent	Used primarily with water, salt water, Freon; poor against most lubricants, solvents, hydraulic fluids and industrial chemicals
Metallic Packings (aluminum copper, lead)	–70 to 1000 fiber-filled; packing good to 212 only	Must be matched to shaft material; shaft finish and size tolerance must be held closely	Solvents, hydraulic fluids, most industrial chemicals, steam, etc. limited only by metal corrosion
COMPRESSION PACKING MATERIAL			
Asbestos	To 600	Good on smooth shafts only	Hot water, superheated steam, hot oils, air and other hot gases
Fibers (jute, flax, linen, duck)	To 212	Good; R_c 28 or harder and 10 rms or better shaft finish recommended	Cold and hot water, low pressure steam, oils, ammonia

III—OPERATING CONDITIONS FOR BASIC SHAFT SEALS

	SPRING-LOADED TYPES		NON-SPRING-LOADED TYPES	
	Leather	 Rubber	Leather	Rubber
SHAFT SPEED, fpm — Shaft speed is the prime factor in selection of the proper seal. It affects the limitations of all other operating conditions, thus it is shown as slow, moderate or high expressed in feet per minute.				
Slow	0 to 800	0 to 1000	0 to 300	0 to 500
Moderate	800 to 1500	1000 to 2000	300 to 600	500 to 1000
High	1500 to 2000	2000 to 3000	600 to 1000	1000 to 2000
TEMPERATURE LIMITS, °F — Temperature limits are the fluid tomperatures of the medium to be sealed. They represent the point beyond which the sealing material or medium sealed become ineffective. Operation at higher or lower temperatures can be accomplished by the use of special compounds under controlled conditions.				
Continuous	−65° +200°	−65° +225°	−65° +200°	−60° +225°
Intermittent	−65° +225°	−60° +250°	−65° +225°	−60° +250°
PRESSURE, max psi — Standard design fluid seals are not intended to withstand pressure. Any internal pressure materially reduces seal life, and means should be provided to relieve internal pressure build-up. Special seal design is required for high-pressure sealing.				
Slow	15	10	0	25
Moderate	10	7	0	10
High	5	5	0	5
SHAFT FINISH, max microin — Fine shaft finishes assure maximum sealing efficiency. The coarser the finish, the greater the risk of leakage and wear on the seal. Surface finish value (RMS) is not, however, the only criterion for shaft finishes. Type of finish, direction of finishing marks, and spiral lead are all factors. Polished or ground finishes with concentric finish marks are preferred. When a finish lead is present, its direction should lead the fluid inward.				
Slow	25	25	25	25
Moderate	20	20	20	20
High	20	20	20	20
SHAFT HARDNESS, suggested Rockwell — Successful sealing is possible on shafts as soft as cold rolled steel. Better performance and longer seal life are obtained, however, on shafts above C20 Rockwell. Fluid starvation, abrasives, and high surface speeds require hard shafts.				
Abrasives	above C-45 above B-80	above C-45 above B-80	above C-45 above B-80	above C-45 above B-80
No abrasives				
SHAFT TO BORE MISALIGNMENT, Total indicator — This is misalignment of the center of shaft rotation with bore center, which causes wear on one side of the seal. This condition becomes more severe as surface speeds increase. (See "Shaft Runout" below.)				
Slow	0.010	0.015	0.005	0.005
Moderate	0.005	0.010	0.005	0.005
High	0.005	0.010	0.005	0.005
SHAFT RUNOUT, Total indicator rpm — This is misalignment of the sealing surface on the shaft with the center of shaft rotation, or movement of the center of shaft rotation through bearing looseness or shaft whip. This type of eccentric wear is more evenly distributed about the circumference of the sealing lip. Runout should be kept to a minimum. Combination of shaft runout with shaft-to-bore misalignment imposes very difficult sealing conditions.				
0–800	0.010	0.025	0.003	0.005
800–2200	0.005	0.020	0.003	0.005
2200–4200	0.003	0.015	0.003	0.005

tivity to dimensional variations; and tolerance of a variety of lubricants and lubricating conditions. Basically, there are four variations of shaft seals, or a combination of these four. Recommended operating conditions for these are given in Table III, and the most useful combinations are shown in Table IV.

A special version is the dual-purpose seal, Fig 12, which incorporates the liquid and dust lips in a single unit bonded to the seal ring.

External-type synthetic shaft-seal, Fig 13, is used where the bore rotates—but seldom where the shaft rotates, because centrifugal force has a large effect on the sealing member and results in performance charactertistics inferior to conventional types.

Suitable shaft finishes are important for performance of shaft seals. One way to minimize the expense and bother of shaft finishes is to use unitized seals, Fig. 14, where the wear ring is an integral part of the seal. Sometimes they also solve difficult installation problems, and usually can be supplied in all the basic shaft-seal types.

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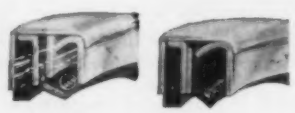
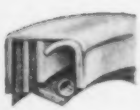
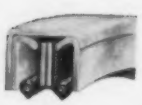
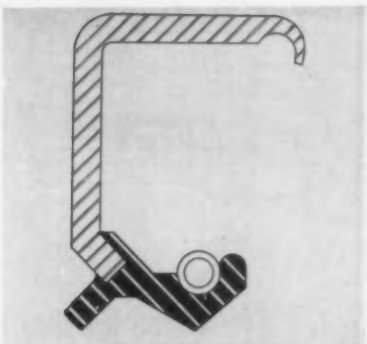
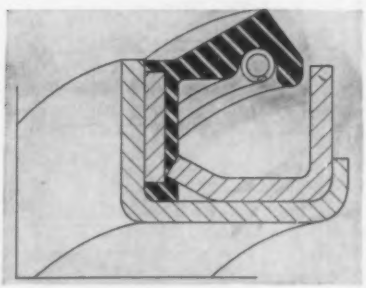
IV—COMBINATION TYPES OF SHAFT SEALS

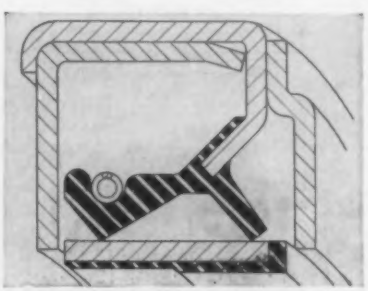
	LEATHER	SYNTHETIC
		**A felt auxiliary** adjacent to the leather or synthetic lip is recommended where external conditions require the added protection.
		Designed for applications where shaft enters seal from the spring-loaded side; the leather or synthetic auxiliary lip acts as a dust baffle.
		For applications where the shaft entry is from the auxiliary side. The leather auxiliary is intended to prevent the entry of dirt or other foreign matter.
		This design basically consists of two sealing members facing opposite directions for separating two fluids. The synthetic seal is designed for separating low-viscosity fluids where positive sealing is required, especially at higher speeds and temperatures.
		This design has two sealing members facing in the same direction for special operating conditions where inner lip is needed to stem a heavy flood of lubricant or surge pressures, and second lip is free to function under normal conditions. Synthetic type is for very unusual conditions where the hydraulic action is so severe that a single lip seal is incapable of providing zero leakage.



12 . . . INTEGRAL DUST LIP is incorporated in this special version of shaft seal.

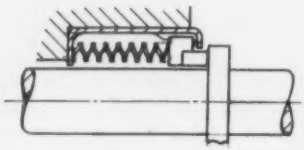
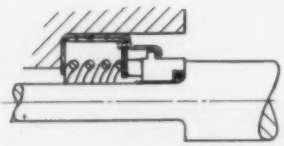
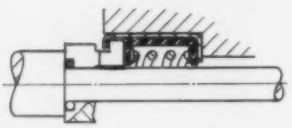
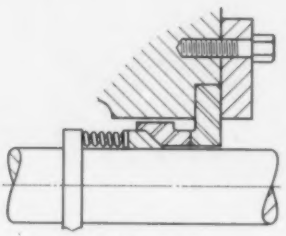
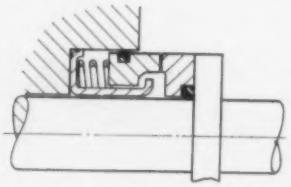
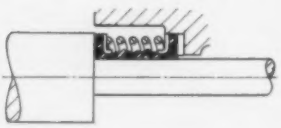
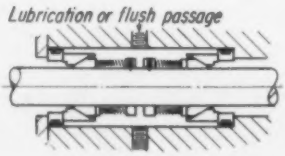
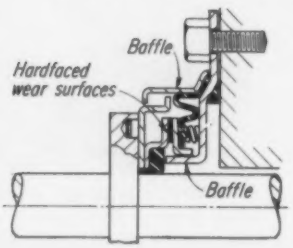


13 . . . EXTERNAL-TYPE SHAFT SEAL is one where the bore rotates.



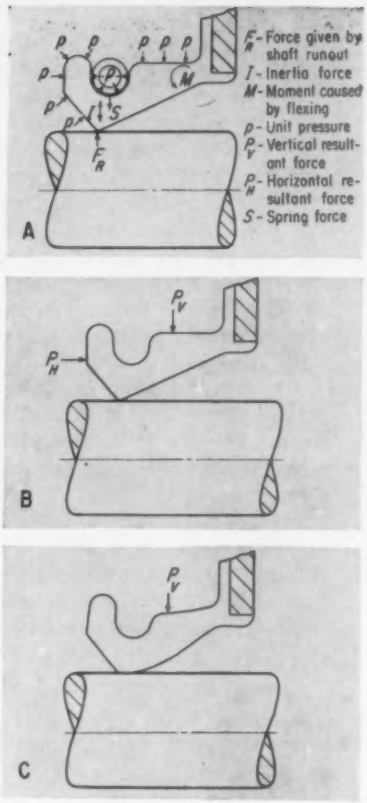
14 . . . SHAFT FINISHES A PROBLEM? One way to minimize it is to use a shaft seal with an integral wear ring—usually pressed on the shaft.

V—APPLICATION RANGE FOR BASIC FACE SEALS

	Description	Temperature, °F	Pressure, psi	Speed, fpm	Comments
	Metal bellows, carbon face	−65 to +650	200	15,000	Inert to many chemicals which degrade elastomers. Bellows and face materials available in a wide range of materials.
	Unitized with O-ring sealing of mating face	−30 to +300	15	5000	Readily available in stock sizes for pumps, etc. Pressure limit is low because of diaphragm type of bellows. Unitized principle is often applied to other designs.
	General-purpose bellows or boot seal	−30 to +250	250	15,000	Allows large axial movement because of spring type and bellows construction
	Teflon-wedge packing	−65 to +500	2000	15,000	Especially suitable for corrosive liquids and high temperature, as well as pressure.
	O-ring packing	−30 to +300	750	15,000	Moderate-pressure, high-speed seal
	Inexpensive bellows type	−30 to +250	0–15	5000	Inexpensive low-pressure design for mild service. Bellows construction limits pressure. Face often seals on housing or shaft shoulder, depending on particular seal design.
	Double installation with flushing	−65 to +500	2000	15,000	Flushing permits cooling, prevents escape of toxic fumes, serves where auxiliary seal lubrication is necessary.
	Track-roller type	−65 to +300	0–15	5000	Design especially suitable for low-speed, very abrasive conditions. Hard facing on both faces resists wear. Unitized design also includes dirt baffle.

Two factors that can limit the use of shaft seals are pressure (or vacuum), and temperature. High temperatures cause hardening and degradation of rubber or leather elements in the shaft seal. Adequate lubrication and auxiliary cooling may be used to keep temperatures low. Another method uses sealing elements with low compressive force on the shaft. Reducing rubbing speed, shaft runout and misalignments is also helpful. For applications with inherently high- or low-temperature problems, special compounds such as the polyacrylics are required.

Pressure sensitivity of shaft seals is inherent in their design; although some have been used successfully up to 100 psi. Typical action of forces on a shaft seal are shown in Fig. 15. In (A), in order to have equilibrium at the lip, the spring force S and the flexing moment M must counterbalance three forces: F_R, the force caused by shaft runout; I, the inertia force; and the opposing components of the unit pressure P. Generally, all these various forces can be resolved into two forces, P_H and P_V acting horizontally and vertically as in (B). P_H tends to displace the sealing element along the shaft and with high enough pressure may blow the lip out. In the usual sealing element configuration, however, the vertical force P_V is larger and tends to flatten the sealing element on the shaft as in (C) well before such blowout occurs. The high contact pressure and resultant high contact width causes excessive heat generation which hardens and degrades the sealing element material. This, in turn, causes cracks in the contact surface which become leak channels. Using a harder compound, shortening and thickening the seal element, and using an abrasion resistant compound can improve the performance. But such changes would also cause lower runout tolerance, higher initial heat generation, and in general shorter life. For this reason shaft seals are best for low pressures.



15 . . . ACTION OF FORCES on a shaft seal (A) can usually be summarized into two forces acting at right angles, shown in (B). For proper sealing, vertical force should be greater—but if excessive it will flatten the seal as in (C) and cause excessive wear.

Face Seals

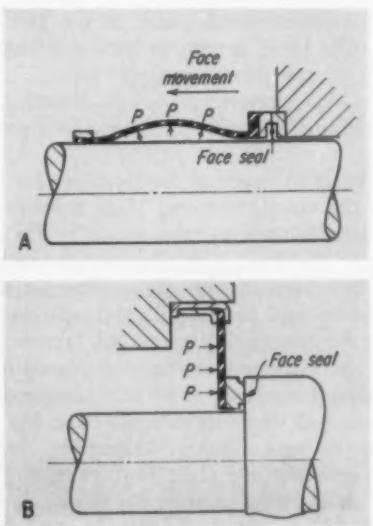
These complement shaft seals, and the following three features are inherent in their design:

- High speeds and pressures are readily handled with appropriate designs.
- They can be made of metals, elastomers, plastics, leather, cork, or other materials to suit a wide range of applications.
- The faces are usually lapped to within a few light-bands of flatness (0.000,030 in.) to provide a fine seal.

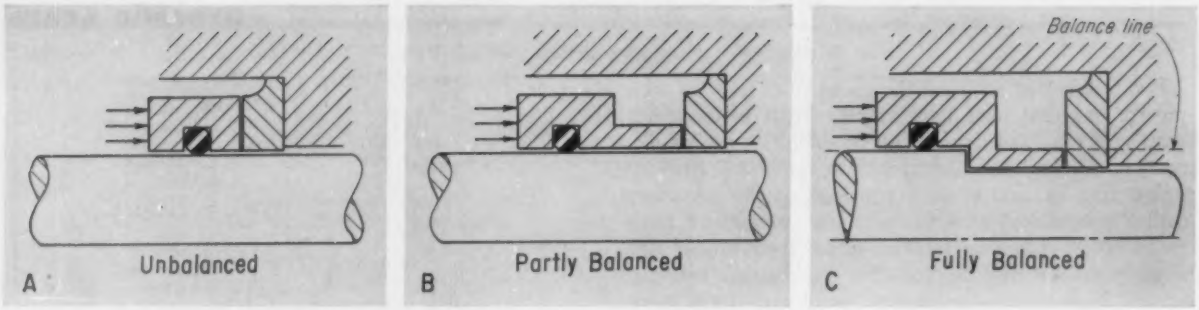
Although face seals are not as standardized as shaft seals, they fall into approximately eight types (Table V). Variations of these types can usually be made for internal or external sealing, and either rotating or nonrotating.

In the table all high-pressure seals except the metal-bellows type have a sliding packing (sometimes called static seal) instead of bellows, or diaphragm. This is because the projected areas of a bellows or diaphragm are so great that the resulting force is sufficient to overcome the spring force. This may cause the spring to bind or may overcome the spring Fig 16(A) or it may overload the face if the pressure is from the inside as in Fig 16(B). The effect is similar to that of vacuum acting on the bellows or diaphragm.

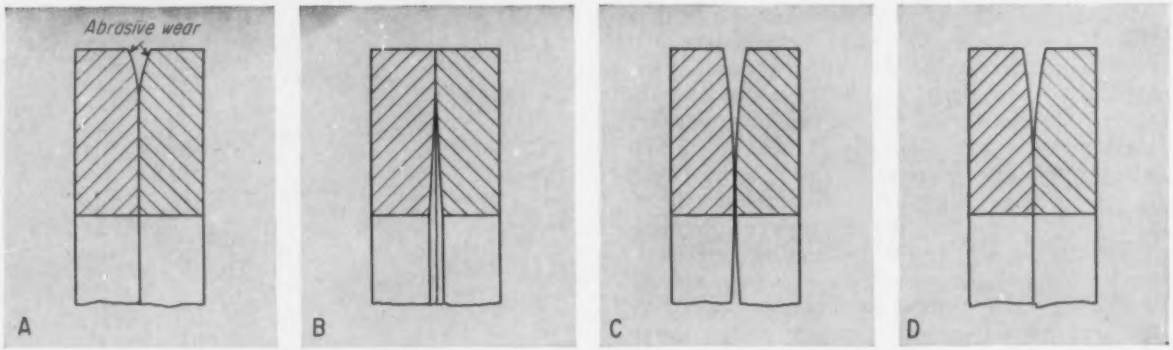
Face seals for high pressure incorporate a pressure-balanced design with various degrees of balance (Fig 17). The unbalanced type (A) is generally for low pressures



16 . . . IN FACE SEALS, use of bellows or diaphragm is impractical because pressure causes bellows to bind and face to lift as in (A), or give excessive face pressures as in (B).



17 . . . FOR HIGH PRESSURES, face seals use static O-rings as secondary seals with various degrees of pressure balancing.



18 . . . To prolong life of face seals in abrasive applications faces are sometimes made concave. Dirt entry and wear on a flat face as in (A) promotes early failure. Wear on a concave face as in (B) results in progressively exposing a new contact surface as in (C) and (D).

that will not affect adversely the lubricating film between the sliding faces. The partly balanced (B) is used where one wants a portion of the fluid pressure to complement the predetermined spring force acting on the sealing faces. Generally, this is desirable in medium-pressure applications where surge pressures could separate the sealing faces and cause leakage. The partly unbalanced pressure acts as a safety factor to keep the sealing faces together. For high pressures it is sometimes desirable to use the fully balanced type (C). Here, the spring force must be designed to take care of any pressure surges. Most face seals of moderate to high pressure are partly balanced. Special constructions using this principle are good for pressures up to 5000 psi.

One of the most exacting specifications for face seals is quality of the mating surfaces. There are many theories about how smooth these surfaces should be for minimum friction on the one hand, and effective lubrication on the other. For minimum friction the surfaces are sometimes specified smooth and flat to within 3 microin rms, but for effective lubrication micropools of lubricants are required, and this suggests that the finish should be coarser. Many finishing techniques have been designed to compromise these two opposing requirements, but they are still subject to experimental verification. In general, where abrasion resistance must be high and leakage requirements low the faces must be flat to within three light bands (0.000,030 in.), surface finish as good as possible (3 rms desirable), hard (66 R_c), and structurally dense as possible.

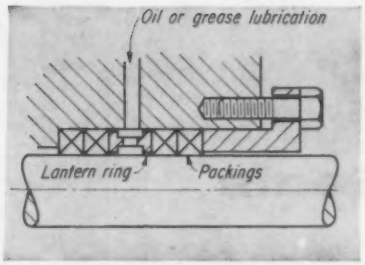
There are, however, some helpful precautions—particularly in dirty applications. One of the most effective is shrouding or adding a dirt baffle. Abrasive wear usually occurs first as a rounding-off of the outer edges of the face seals, Fig 18(A). Where a dirt baffle is insufficient to counteract this type of wear, face seals can be lapped to a spherical or conical shape; Fig 18(B) gives an exaggerated view. This has a tendency to extend seal life so that, as the outer edges wear, the contact area moves toward the center, Fig 18 (C and D).

Compression packings

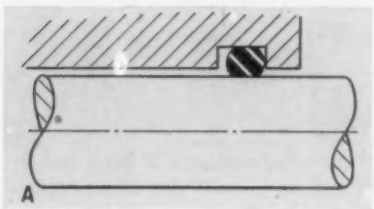
The design variations here are usually limited to selection of materials to suit the operating conditions, and these will be found in Table I. Typical design, (Fig 19), is sometimes used in rotating applications. However, compression packings in general are best suited for high-pressure reciprocating, or combination of reciprocating and rotating motion. Some designs will hold pressures up to 10,000 psi, but lubrication and surface speed are usually limiting factors. Since friction is so high in this type of seal, speed is usually limited to 1000 fpm, except in centrifugal pumps where water seepage through the seal can be used to lubricate and cool it.

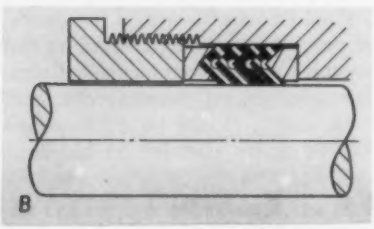
The temperature limit for fiber and combination fiber-rubber packings is about 250 F; for asbestos, about 700 F; and for metallic or metallic-covered packings, to 1500 F.

Packings have a tendency to score the shaft more than do most other types of contact seals. This is because foreign particles tend to enter and become imbedded in the packing. Cleanliness is necessary and the shaft should be as hard and smooth as practical. Separate wear rings can be installed where scoring is likely to damage an expensive shaft.

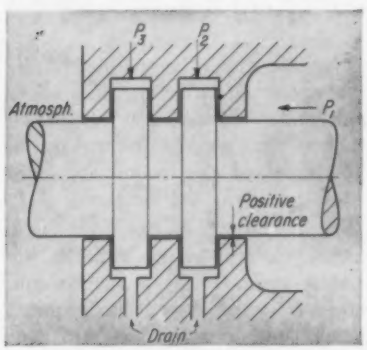


19 . . . COMPRESSION PACKING in this typical design for low rotating speeds uses oil or grease pocket.





20 . . . MOST POPULAR TYPES of molded packings are O-ring (A) and V-cup (B).



21 . . . LABYRINTH SEALS are designed to limit the leakage in accordance with various empirical formulas which have been derived from the well-known Martin formula.

FOR COMBINED REPRINT of "How to Choose a Dynamic Seal" and "How to Specify Dynamic Seals," just check 594 on one of the Reader Service cards found in this issue.

Molded Synthetic Packings

Designs here are available in a variety of geometric shapes, such as O-ring, V-cup or U-cup. They may also be found in the shape of an X, a D, a square or even a triangle. Each variety is supposed to minimize extrusion under pressure when it is installed according to instructions. The O-ring and V-cup (Fig 20) are the most popular, but not usually recommended for rotating service. They are most suitable for high-pressure static and reciprocating service. O-rings, however, can be used at speeds up to 100 rpm at low pressure. V- or U-cups will work up to 1500 psi in applications that combine reciprocating and low-rotating motion.

Back-up or end rings of leather are often used with O-rings and packings, primarily to prevent extrusion but also to help maintain lubrication. If the sealed medium does not provide adequate lubrication, grease or oil fittings are needed for auxiliary lubrication, as shown with compression packings.

Labyrinth or positive clearance

These seals are so specialized that no standard types or designs have evolved. Design is usually controlled by the tolerable leak-rate, from which one can calculate gap clearances and number of elements required.

1. **Number of rings** to limit leakage to a given flow can be found as follows:

$$N = (40\,P - 2600)\,(W/A)/540\,(W/A) - P$$

where N = Number of rings
W = Permissible leakage, lb/sec
A = $C\pi D$, cross-sectional area, in.^{2}
C = Clearance, in.
D = Diameter, in.
P = Absolute pressure, psia

In this equation, to find N_{12} for a leakage from pressure level P_1 to a lower pressure level P_2, the N for each must be found, then $N_{12} = N_1 - N_2$.

2. **Leakage flow rate** can be found as follows:

$$W = 25\,KA\sqrt{\frac{\left(\frac{P_1}{V_1}\right) - \left[1 - \left(\frac{P_2}{P_1}\right)^2\right]}{\left[N - \mathrm{Log}_n\left(\frac{P_2}{P_1}\right)\right]}}$$

where W = Flow rate, lb/hr
V_1 = Initial specific volume, ft^3/lb
K = Experimental coefficient

For interlocking labyrinths, $K = 55$ approximately, if the velocity is effectively throttled between labyrinths. It is independent of clearance in the usual range. For non-interlocking labyrinths, K varies with ratio of labyrinth spacing divided by radial clearance. For a ratio of 5, $K = 100$; for a ratio of 50, $K = 60$.

EDITOR'S NOTE: For additional information on design and application of mechanical seals, see:

How to Apply O-rings, Aug '57, p 176—Summarizes effects of various factors such as fluid pressure, surface finish, eccentricity of shaft and bore, and elastomer hardness.

Gasketed Joints for Electrical Equipment, Mar '57, p 183—Covers the design criteria, characteristics of ideal gasket material, 8 common material types.

Rotating Seals for High Pressure, Feb '56, p 140—Gives effect of hydraulic balance, structural design, packing and seal-face materials, and selection of seals for severe operating conditions.

High-temperature Seals, Jan '56, p 151—The factors affecting design of glands for sealing reciprocating or rotary motion under extremes of heat and pressure—with recommendations for seal materials, gland design, lubrication and surface finish.

—Frederick Marich

How to Specify Dynamic Seals

A standard form, like the one shown here, coordinates the work of customer and manufacturer, and simplifies even the most complicated seal problem.

RICHARD J MATT
Bearing and seal specialist
Thompson Ramo Wooldridge Inc, Cleveland

What next?—After the pertinent requirements for a dynamic seal have been agreed on. The problem now is finding an orderly way to exchange information between your engineering and purchasing departments, and the seal manufacturers. A most convenient way to handle this is to develop a standard form (like the one at right) specifically designed for dynamic-seal applications. Operating requirements on this form should be clearly defined so that there is a common understanding by all parties concerned.

In using this form the customer lists operating requirements as fully possible, notes any special conditions, such as corrosive environment and long-time storage, under "comments," and illustrates space limitations by means of a sketch on the form, or by supplementary drawings.

With this information the seal manufacturer can supply a certified seal-assembly drawing, including operating ranges that may have been omitted by the customer. If all information on the drawing is acceptable, the customer incorporates it on his letterhead; any subsequent changes in operating conditions or configuration constitute a drawing change, and must be coordinated with the seal manufacturer.

This orderly exchange of information ensures continuous certification of the seal-assembly drawing, and prevents faulty applications, which are usually blamed on the seal manufacturer or vendor. It also expedites the work of reliability and quality-control departments.

How to define operating requirements

Here are details about the checkpoints in the standard form.

1 . . . Normal operating speed (rpm) is the actual operating speed of the unit.

2 . . . Runaway speed (rpm) is the maximum speed in case something happens to the control device.

3 . . . Ambient-temperature range refers to temperature surrounding the over-all unit (pump). This is important where heat soak-back is possible.

4 . . . Pressure at P_1 should be specified as a maximum. Where fluids are sealed against air, P_1 of the fluid is normally on the outside of the seal ring OD. Where intermittent negative pressures occur, the full range should be specified—for example 15 in. Hg to 300 psi. This is important to the seal manufacturer, and if he is not informed of it a leaking seal may result, due to inadequate seal pressure balance considerations.

5 . . . Pressure at P_2 should be specified as a maximum. Where burst or proof pressures are being exerted on the seals, these should be noted under "comments." Excessive burst or proof pressures are not recommended, and the proof pressure for a casting should be distinguished from the reliability of the entire assembly to handle a given pressure.

6 & 8 . . . Medium at P_1 and P_2 should be specified as air, oil, grease, etc. Where special concentrations of the fluid are known, these should be given: for example, 20% H_2SO_4.

7 & 9 . . . Temperature at P_1 and P_2 should be specified as full range.

10 . . . Required operating life should be specified as the actual life desired, without any safety factor. If a safety factor is desired, note it under comments as an over-all "design life." Such information is used by the seal manufacturer to select seal materials and give recommendations for mating materials to be used in the mediums at P_1 and P_2.

11 & 12 . . . Operating Cycle—wet or dry indicates the duration of one wet or dry cycle. If the unit runs continuously wet, the wet cycle would equal the required operating life. If the unit runs on a cycle of one hour wet and two hours dry for 100 cycles, this would mean a design life of 300 hours; the wet operating cycle would be one hour, and dry operating cycle two hours.

13 . . . Spring rate should be specified for "metal bellows seals" only and noted under comments. This is useful to seal designer and inspection departments for quick comparison with other seal assemblies, because it indicates whether the assembly may be too stiff or soft.

14 & 16 . . . Minimum or maximum operating heights are important because they indicate the tolerance range of the seal assembly. In many seal applications, particularly with metal bellows that have high spring rate, this is critical because the face loads increase rapidly with seal deflection.

15 & 17 . . . Minimum load at maximum operating height and maximum load at minimum operating height together indicate the desired face-load operating range for a specific application. Since the seals are normally spring-loaded,

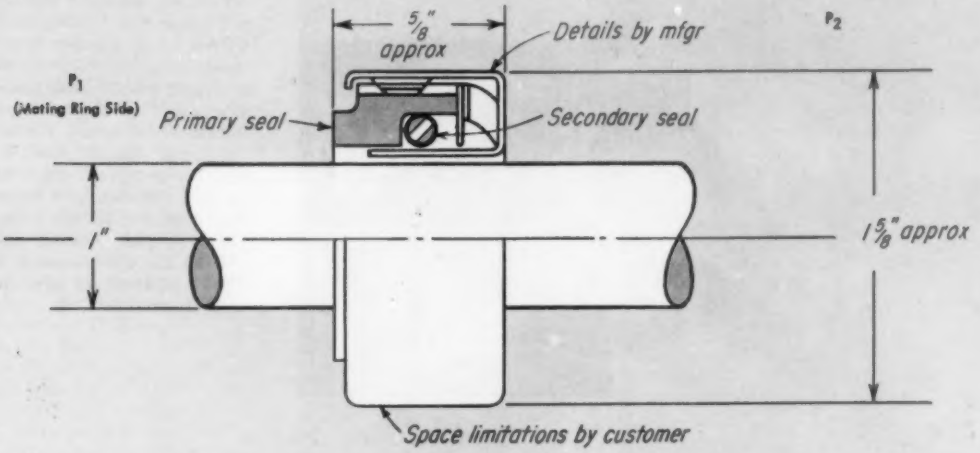
Thompson Ramo Wooldridge Inc.

SEAL APPLICATION

Tapco Group

APPLICATION (Gear Box, Fuel Pump, etc.) Water Pump

FOR USE IN F-709



1. Normal Oper. Speed (rpm)	12,000	12. Oper. Cycle-Dry (hr.)	4 min.
2. Runaway Speed (rpm)	13,280	13. Spring Rate	to be determined by mftr.
3. Ambient Temp. Range (°F)	-65 to +250	14. Max Oper. Hgt. (in.)	" "
4. Pressure at P_1 (psig)	130 to 180 *	15. Min Load at Max Oper. Hgt. (lb)	3
5. Pressure at P_2 (psig)	atmos. sea level to 50,000	16. Min Oper. Hgt. (in.)	determined by mftr.
6. Medium at P_1	water	17. Max Load at Min Oper. Hgt. (lb)	5
7. Temp. Range of P_1 (°F to °F)	+40 to +160	18. Seal-ring Mat'l	carbon usg 39
8. Medium at P_2	Air (traces of Mil-H-5606)	19. Seal-ring Flatness—(Helium Light Bands)	2 min.
9. Temp. Range of P_2 (°F to °F)	-65 to +250	20. Secondary-seal Configuration	O-ring
10. Min Req'd Oper. Life (hr.)	250	21. Secondary-seal Mat'l	Buna -N
11. Oper. Cycle-Wet (hr.)	1 min.	22. Max Permissible Seal Leakage	2 drops/min. (static) 10 drops/min. (dynamic)

Item (13), Spring Rate, is required for metal bellows only.

COMMENTS: * Surges to 400 psi for 0.025 sec; proof pressure, 750 psi static

Submitted By: R. J. Matt Date 2/9/61

the face load varies with the assembled height of the seal. It also varies with the medium being sealed.

18 . . . Seal-ring material for new applications involves evaluating a number of other operating factors and is usually selected on basis of experimental data and recommendations of seal manufacturers. Final selection should be in terms of identifiable commercial specifications (i.e. Flex Carbon P751).

19 . . . Seal-ring flatness is often the key to successful sealing, and in such cases flatness should be determined in the loaded condition. In many instances, seal assemblies will be flat in the unloaded state, but not when operating loads are applied. This flatness at load is very important in the case of high-speed rotary equipment sealing aviation fuels, which require a minimum flatness of two light bands. With labyrinth seals, on the other hand, this item does not apply and is left blank.

20 & 21 . . . Secondary-seal configuration and materials usually depend on detail design of the seal assembly as well as other operating factors. Final specification of these items is essential for uniform certification of the seal assembly as a whole.

22 . . . Maximum permissible seal leakage is a final criterion of the seal requirements. Where possible, such leakage should be specified in terms of cubic centimeters per min. or other volumetric measure.

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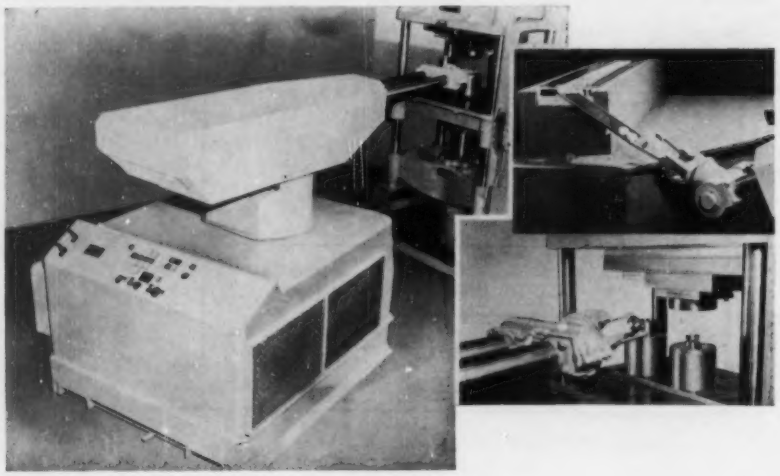
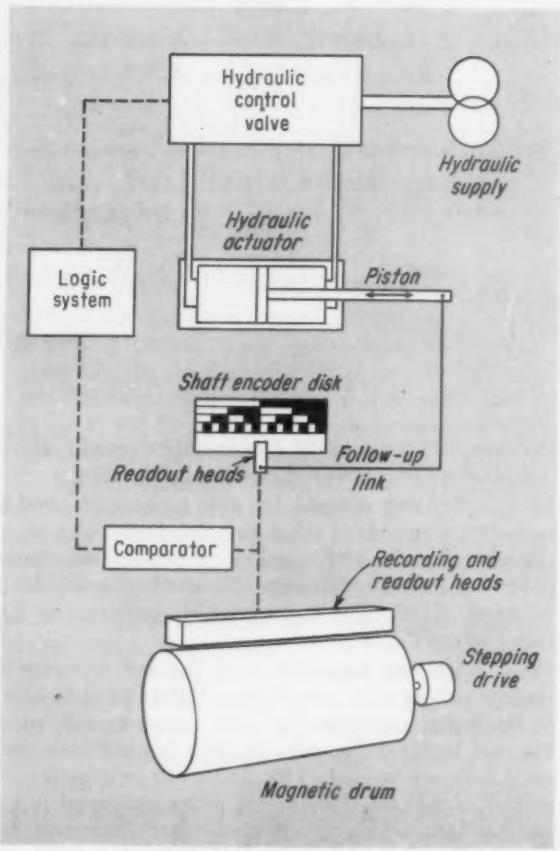


TYPICAL JOB for the manipulator is a 2-stage hot forging-press operation. Fitted with slender fingers, the unit removes a heated slug of metal from a supply chute and places it on the first die. The hand retracts, and robot actuates the press. When press opens, the hand lifts the work from first die, turns it over and sets it on second die. It then places a new billet on the first die and again actuates the press. Hand removes the finished piece from the second die and places it in a tote box. These operations are repeated until unit is switched off.

Pushbutton Robot Learns Fast

It's a copycat arm. Just guide it through the routine once and it remembers and accurately reproduces complex work procedures. Control circuits of the manipulator are governed by magnetic memory drum.

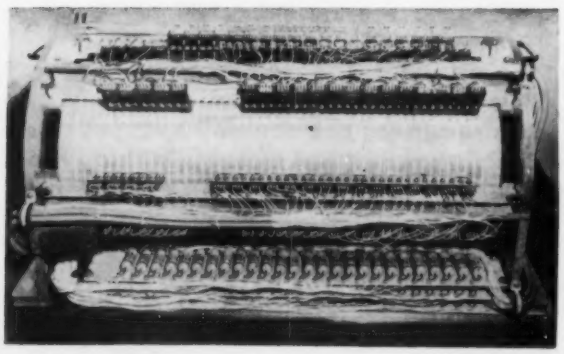


HYDRAULIC ACTUATOR controls power for arm movements by means of a solenoid flow-control valve. The code disk of the shaft-position encoder is linked with the actuator. Each possible position of the arm's hydraulic actuator has a corresponding code designation. When the arm is being taught the program, it is moved to the position for a given step, and the corresponding coded information is stored on the drum. To return to this position during the robot's working cycle, the code for the actual position of the arm is compared with the desired position and the difference is determined by the comparator. The logic system operates the control valve to move the actuator in the proper direction to reduce this difference to zero. Actuator moves at maximum velocity when the error is large, and slows by partly closing the valve as the error is reduced.

When actuator arrives at the desired position, the comparator sees the same code number from both the drum and the encoder and the logic system closes the valve, halting the actuator, and rotates the drum to the next command. Similar systems control the other movements.

ROBOT LEARNS from an operator who guides it through the entire program, using a set of six pushbuttons controls—each on a different side of a cube clipped onto the mechanical arm. These extend or retract the arm and rotate the turret. The two pushbuttons on the wrist control pivot the hand holder 220° vertically. The hand control has two pushbuttons and a snap switch; the buttons rotate the hand 180° in either direction, the switch opens and closes the hand. Record-control held in operator's left hand incorporates a dead-man switch. It stops all movement if the control is released from the hand.

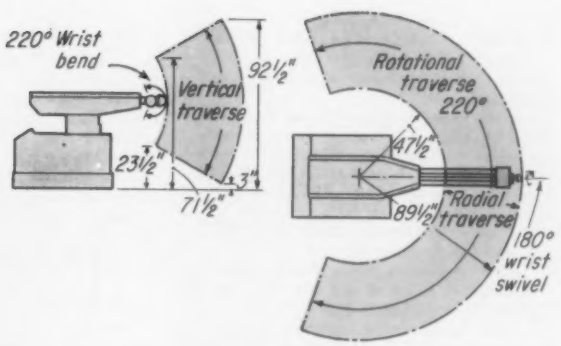
To teach the manipulator a program, the operator guides the arm and hand to the first position, then presses the record button. This actuates amplifiers which drive the recording heads, impressing a magnetic pattern on the drum. The drum then steps to the next position to receive the pattern corresponding to the next position of the arm. The position and record steps are repeated until the entire program is on the memory drum. Drum records only the position of the arm at the moment the record button is pushed; intermediate steps to reach the position recorded are ignored.



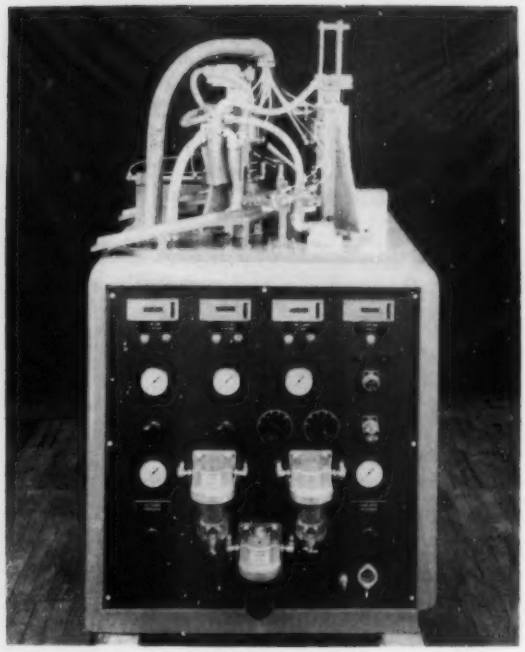
MEMORY DRUM has stationary readout; pickups respond to flux intensity rather than rate of change of flux. After a sequence of movements has been recorded, the manipulator repeats this cycle indefinitely. When the repeat button is pushed, the drum steps to its first position. The magnetic readout heads detect the pattern and initiate movements to bring the manipulator to the position indicated by the recorded pattern. The drum then moves on to the next step in the routine and the action is repeated until the learned routine is completed.

The drum has a capacity of 16,000 bits recorded in 200 rows around the circumference, with 80 bits per row. Each of the 200 rows represents a distinct movement.

Eighty bits are needed in each row to control all of the functions the machine may need to make one movement and to actuate auxiliary equipment.



PS . . . Unit has large selection of "hands" that enable it to perform wide variety of jobs; and its range of motions enables it to reach objects within a swept volume of 350 cu ft. At full speed, weight limit is 25 lb; at reduced speed, 75 lb. Power for the arm is supplied by hydraulic servos and the hand clamp is pneumatically actuated. This self-contained 2700-lb unit plugs into 440-v 60-cps source, can be moved from job to job by fork truck. UNIMATE is produced by Consolidated Controls Corp, Bethel, Conn.



Seal-checker Spots Early Leakers

By duplicating a wide range of conditions, this lip-seal tester proved need for 100% quality control. It was followed by equipment that checks seal five ways to eliminate premature failure.

THE BASIC STUDY that prompted development of seal tester and checker produced the following conclusions concerning lip-seal application:

Shaft finish is important to long seal life; however, too high a finish is detrimental. In general, shaft finish of 10 to 15 microin is best—maintains a thin film of lubricant between shaft and seal.

Seal-installation methods influence seal life, primarily because they affect finish of the shaft surface.

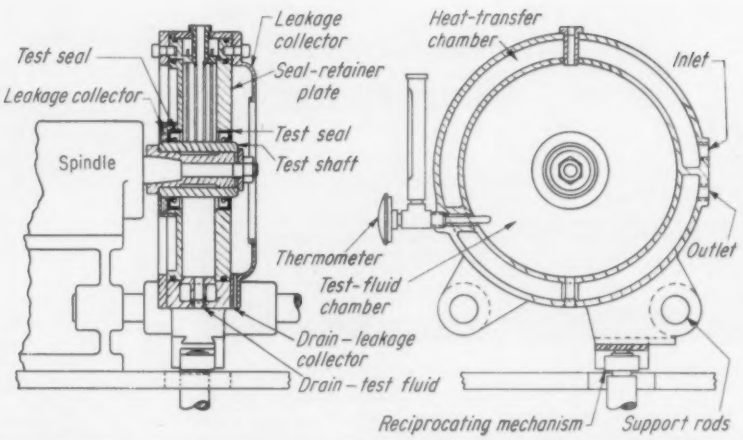
Other conditions being equal, there is an optimum range of seal diameters for a given shaft size.

There is a narrow optimum range of pressures exerted by the seal on the shaft. This pressure is result of trim interference, garter-spring tension, and composition of the sealing element. All of these are variable in an actual production run.

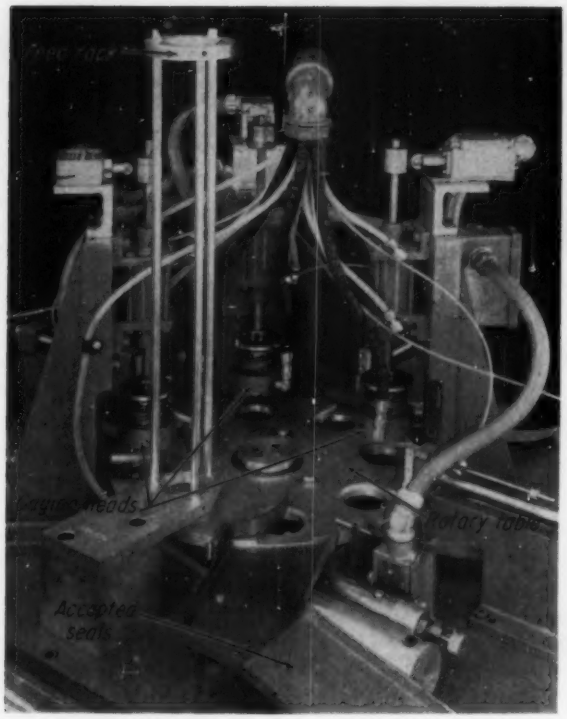
Temperature of sealed fluid cannot be taken as an indication of point-of-seal temperature. Localized temperatures up to 400 F have been recorded with fluid maintained at about 150 F.

Tight-fitting seals do not "wear in" to proper running size. They "machine" the shaft, are damaged by the heat of friction, and become early "leakers."

Current lip-seal manufacturing methods cannot be relied on to maintain specification tolerances desired. It is necessary, therefore, to test seals 100% before installation.

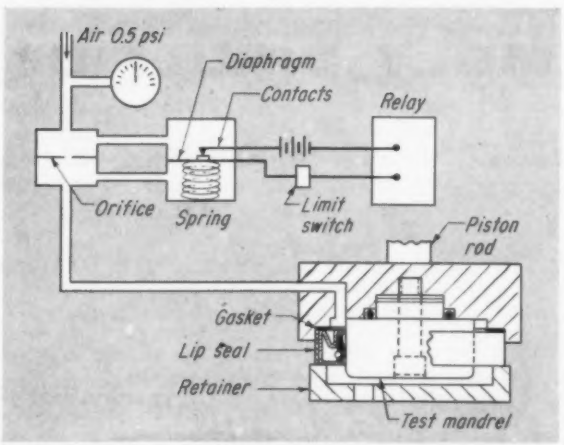


SEAL TESTER is self-contained unit including a variable-speed drive for the test shaft; a mounting system to hold seals up to 10 in. dia; oil heater and pump for elevated temperature testing; plus a control panel for the selected test mode. Housing in which seal retainer plates are clamped is mounted on support rods—they allow sliding it away from the test shaft for assembly and inspection. An oil pump and heater assembly circulates oil through the test-fluid chamber to maintain desired temperature. When tests are run with a variety of oils, the test-fluid chamber can be filled with the test lubricant. Only two quarts of oil are required, and temperature is controlled by passing heated oil through the heat-transfer chamber. Reciprocating mechanism slides the housing back and forth on the support rods. This permits evaluating the effects of axial movement combined with shaft rotation on seal life.

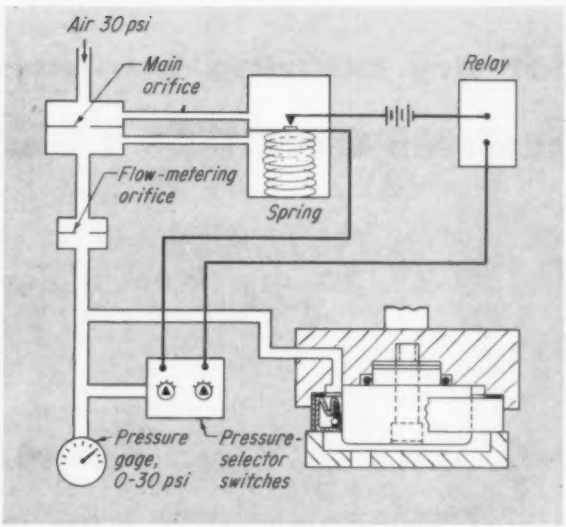


SEAL CHECKER is an 8-station air-operated turret table which passes production seals through checking and reject stations. Seals are checked for max and min lip-dia limit and concentricity, plus high and low lip-pressure limits. Intermediate stations after each checking station reject those seals that do not conform to specifications. Counters on each of the reject stations and the final station keep count of all seals passing through the checker. These counters can be used to control deviations as they occur in seal manufacture.

Seals are gravity-fed into pockets in the rotary table. The three checking stations consist of a vertically mounted air cylinder with gaging equipment fastened to the piston rod. A pressure comparator senses airflow between gaging mandrel and oil-seal lip.



A



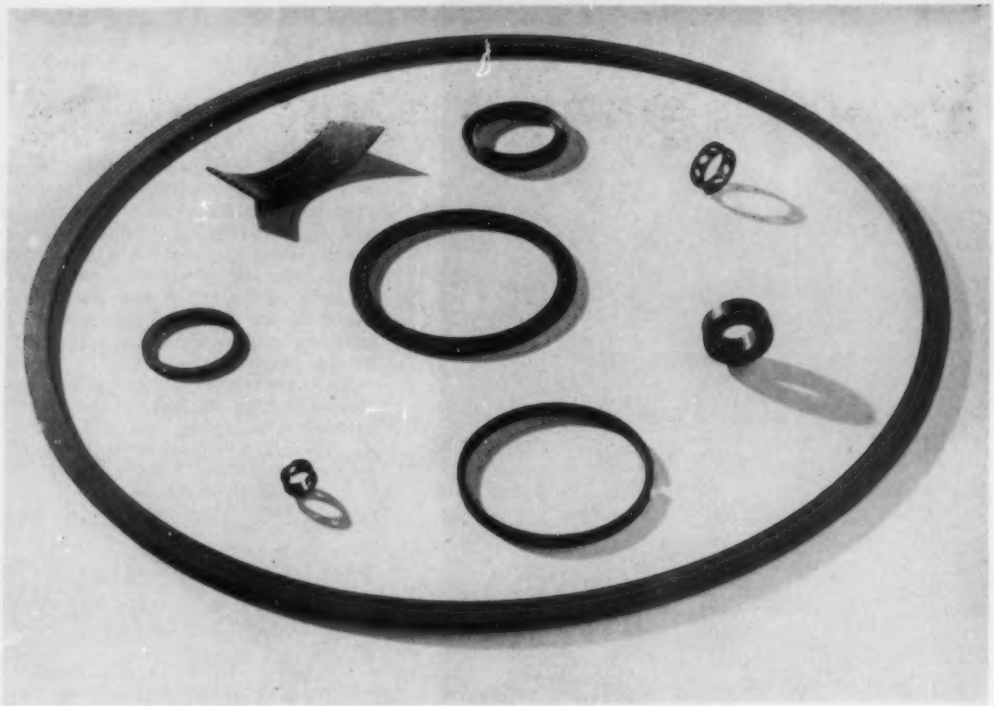
B

FIRST CHECKING STATION A, for undersize lip dia, has contacts on a diaphragm which reacts to pressure differential. Incoming air flexes the diaphragm down, opening the contacts; limit-switch activates circuit. If seal-lip dia is too small, airflow between seal and mandrel is impeded; pressure buildup raises diaphragm and closes contact. Closed circuit triggers relay to next station which activates reject cylinder when table indexes defective seal to next position.

Second checking station, for oversize lip dia, has contacts on diaphragm reversed and are normally open. Incoming air-pressure differential closes points. If seal is larger than largest allowable, pressure does not build up on underside of diaphragm; points remain closed. Limit-switch is activated, circuit is closed and relay to next station actuates reject cylinder when table indexes.

Third checking station, B, for high and low lip pressure, uses an orifice that produces a gradual pressure buildup behind the seal lip. If a predetermined flow rate is reached before pressure reaches a preset limit, seal is rejected. It is also rejected if pressure goes beyond a preset limit before the flow rate is reached. Since seals from different vendors will have different lip-pressure specifications, two pressure-selector switches are provided to set appropriate high and low limits.

PS...Seal-test machine was developed to perform endurance tests under a wide range of conditions. Called Sealrater (SRS), it tests two seals simultaneously under controlled temperature, pressure, and eccentricity at speeds up to 15,000 rpm. Results of test program (see box) indicated need for a 100% dimensional check of production seals. Sealector (SLA) was the result—an automatic production-line seal checker that makes three-dimensional checks on up to 600 pieces per hour. Sealrater and Sealecter were developed by Special Problems Dept of General Motors Research, Warren, Mich.



for dry bearing surfaces like these, try . . .

REINFORCED TFE + MOLY DISULFIDE

Oriented glass fibers make the Teflon strong, and the solid lubricant keeps it slippery.

R C BARRY, *manager*
Product Development Dept
Rogers Corp, Rogers, Conn

When glass fibers are added to Teflon TFE-fluorocarbon resin to increase its resistance to deformation under load, some significant sacrifice in the resin's excellent dry-lubricating ability must be accepted. By specifying up to about 10% molybdenum disulfide (MoS_2) as a second additive, however, you can bring the lubricating properties of the reinforced Teflon to the same level as those of the virgin resin.

Table I shows how this works with laminated sheet material made from glass-reinforced TFE by established papermaking techniques. Dynamic coefficient of friction is kept very close to the value for unfilled TFE over a wide range of contact pressures and surface velocities, while deformation under load is reduced many fold. (Static friction coefficient of the unfilled material is higher because the material is softer.)

Such stability under load, particularly at elevated temperatures, is a valuable characteristic in parts that must slide against metal surfaces at high speeds. Typical of these are the parts pictured above: large-diameter back-up rings (to keep O-rings from twisting), bushings, piston rings, seals, ball-bearing retainers and roll-up liners for metal bushings. All are machined from sheet, rod, or tube material made by molding together many thin layers of filled TFE paper in the same manner that high-integrity insulation for motors or transformers is produced.

Called the beater-addition process, this technique adds a resin emulsion to a dilute suspension of fibers and MoS_2 particles in water, coats the individual fibers with TFE and MoS_2, then forms an individual ply on a papermaking machine. Laminates sintered and pressed from such plies have greater strength and stiffness than filled TFE, because the reinforcing fibers remain unbroken and highly oriented in the papermaking step. Additional strength comes from interlocking of the fibers as they deposit on the paper-machine screen. Tube and rod are usually made by sintering and pressing "green" paper shredded to fill the mold.

Design considerations

For bearing applications there are four main limitations to MoS_2-modified TFE resin reinforced with glass in this manner:

Allowable pressure × velocity (PV) factor is limited to a maximum of about 10,000. Inability to dissipate heat generated by high speeds is also a problem; it limits surface rubbing speed to approximately 200 fpm or 1000 rpm. If favorable cooling conditions exist, these speeds may be increased considerably—as the field-test data of Table II suggest. Experience has also shown better PV ratings when the metal mating surface is fine (50 microinch or better) and hard (Rockwell C50).

Thermal expansion coefficient is widely different in the three coordinate directions, although lower in two directions than virgin TFE. As Table I shows for sheet stock, the thermal expansion is greatest in the thickness direction. For rods and tube stock, the length increase is greater than the radial increase. Here, use the "transverse" figure from the table for radial change, and the "thickness" figure for length change. Where the operating temperature will exceed 400 F and tolerances are close, it is recommended that the filled TFE part be heated to temperature of use before final machining. Parts can be machined to tolerances of ±0.0005 in.

Mechanical properties are lower than for TFE resin reinforced with woven fabric or with oriented filaments.

Parts must be designed for manufacture from sheet, bar or tube stock. Sheet material is most commonly specified and can be die-cut or machined. Only simple shapes—such as chevron packing rings—can be molded from sheet stock because of the interlocking fiber structure. For more complex shapes, a technique is being developed for making preforms by depositing the slurry on a shaped screen similar to the wet slurry process used with reinforced polyester resins (*PE—Feb 22 '60, p 52*).

EDITOR'S NOTE: Recent articles that deal with other aspects of bearing materials selection include these:

For a Stronger Metal Surface, Nov 14 '60, p 70—Practical guide compares the different methods of boosting wear resistance, bearing and fatigue strength.

Bonded Coatings Lubricate Metal Parts, Sep 5 '60, p 48—When bearing pressures are high and velocities low, a bonded-in-place resinous or inorganic coating containing a solid lubricant like molybdenum disulfide or graphite may be the answer.

Choosing a Metal to Resist Wear, Aug 22 '60, p 43—Article shows where to look for those hidden causes of wear, and which properties resist these wear causes best.

How to Avoid Abrasive Contamination of Precision Mechanical Devices, Aug 15 '60, p 51—Normal production cleaning methods are shown incapable of cleaning precision surfaces sufficiently for failure-free operation. Polarized-light inspection method is discussed and proper cleaning steps detailed.

What Fillers Will Do for the Latest Teflon, Sep 28 '59, p 52—Like the older fluorocarbon resins, the copolymer type designated Teflon 100X works better in some applications when it's reinforced. Here are latest design data that show why.

Solid Lubricants for Extreme Pressures, June 22 '59, p 64—Simple press-fit test with bushing and mandrel finds coefficient of friction when surfaces slide at high loads and low velocities. Chart lists values for over 50 lubricant candidates.

—Ford R Park

I—TYPICAL PROPERTIES OF TEFLON FILLED WITH GLASS FIBERS AND MoS_2
(Filled compounds made by beater-addition process)

Property	Test Value		
Reinforcement	None	Glass + MoS_2	Glass
Composition (Teflon/fiber/MoS_2), %	100/0/0	75/15/10	85/15/0
Specific gravity	2.16	2.25	2.15
Durometer hardness (D scale)	50–65	73	72
Friction coeff (vs polished steel)			
Static 4000 psi	0.032	0.022	0.028
Dynamic 4000 psi, 2 fpm	0.018	0.018	0.025
1.5 psi, 20 fpm	0.130[1]	0.140	0.160
Deformation under load (24 hr), %			
122 F, 1200 psi	4–8	0.2	0.2
2000 psi	25.0	0.6	0.6
300 F, 1200 psi	4.0[1]	0.4	1.0
2000 psi	25.0[1]	1.0	2.0
Thermal expansion coefficient, in./in./°F (0 to 100 F)			
Longitudinal direction	5.5[2]	1.6	1.4
Transverse direction	5.5	4.0	4.0
Thickness direction	5.5	15.0	10.0
Thermal conductivity, btu/hr/sq ft/°F per in.	1.7	2.1	1.8
Heat-distortion temp (66 psi), °F	250	500	500
Tensile strength, psi x 1000			
Longitudinal	1.5–3.0	7.0	7.5
Transverse	1.5–3.0	4.0	5.5
Flexure strength, psi x 1000			
Longitudinal	No break	10.0	15.0
Transverse	No break	7.0	10.0
Flexure stiffness, psi x 1000			
Longitudinal	50.0–90.0	215.0	250.0
Transverse	50.0–90.0	170.0	210.0
Izod impact, ft-lb/in.			
Longitudinal, edgewise	3.0	1.5	1.4
Longitudinal, facewise	3.0	2.7	2.2
Transverse, edgewise	3.0	1.6	1.3
Transverse, facewise	3.0	2.5	2.4

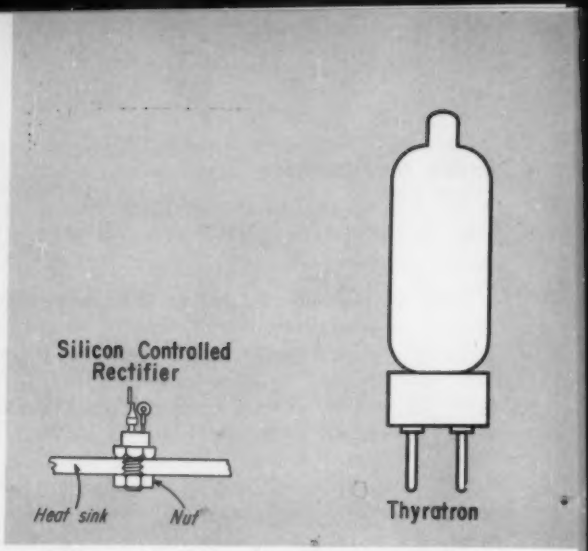
[1] Rogers Corp data. [2] 73 to 140 F

II—FIELD TESTS OF BALL BEARINGS WITH TEFLON-GLASS-MoS_2 RETAINERS
(Run by Barden Corp on its Type SR4H nonseparable angular-contact bearings)

Application	Temperature, °F	Speed, rpm	Operation without failure, hr
Test fixture	400	8,000	1000+
Blower motor	510	6,500	240+
Hi-temp motor	340	10,000	1200+
Tachometer generator	350	4,200	1469+

more about . . .

SCR's vs Thyratrons



In the Jan 2 issue, Baruch Berman compared these two controlled rectifiers and found the SCR usually better. This touched off a controversy which continued at the recent AIEE convention in New York. Here's an evaluation of the questions that were raised.

FRANK YEAPLE, *associate editor*

Controlled rectifiers are 3-terminal electrical switching devices that allow large current flow in the forward (rectifying) direction when a small signal is applied to the control (gate) terminal, and block all current flow in the reverse direction. There are electron-tube and semiconductor varieties; both are widely used in motor speed and other control applications. This much everyone in the field accepts.

But when it comes to saying which is better—the SCR (silicon controlled rectifier) or the thyratron tube—there is sharp disagreement among the specialists.

To get a closer look at the controversy PRODUCT ENGINEERING interviewed key design engineers who work with SCR's and thyratrons. Their views were obtained during the recent winter convention of AIEE (American Institute of Electrical Engineers).

All had read Baruch Berman's article, "SCR's vs Thyratrons," in the Jan 2 issue. Interest in it was extremely high, because controlled rectifiers of both types are doing a dependable job in many variable-speed motor drives, heating and lighting controls, and new applications in other fields are being developed continuously.

THE TWO SIDES

Mr Berman, who uses both thyratrons and SCR's in his designs, maintains that the latter have more advantages. But tube manufacturers and some tube users question certain of his claims for the SCR, and believe that thyratrons, with their long history of development and experience, still have some special advantages.

They ask: how can SCR's be guaranteed for many years of operating life when they haven't been in general use long enough to prove it? (Thyratrons have been used successfully for 30 years.) What about the graduated reduction in allowable rating of semiconductors when ambient temperatures rise? (Thyratrons have essentially constant characteristics through a wide ambient range from about −60 to 170 F.) And can the SCR, which is limited to 500 v for the expensive models and even less for the lower cost models, be used in the 440-v circuits common to industry without sacrificing safety margin? (Thyratrons are available rated up to 1500 v and are not limited by any industrial voltage.)

What's the answer?

These are valid questions, as are many others that are being raised. In some cases the answer depends on the application; in others it is a matter of opinion.

One general answer is given by sales statistics: people buy both SCR's and thyratrons, and there are loyal supporters of each.

Other answers are found in manufacturers' literature. In fact, Berman obtained some of the quantitative figures for his article from suppliers' catalogs.

But perhaps the best answers are the candid ones that emerged from lively interviews we had with the electron-tube and semiconductor experts. Their names are listed in the acknowledgments at end of this article. Here are some of the central issues in the discussion.

Size

Does adding a heat sink eliminate SCR's size advantage?

By their nature, semiconductors need some sort of heat sink to prevent overheating. This heat sink can be the wall of the enclosure, or a separate mounting plate. When the wall is used—with thin mica washers for electrical isolation—there is no size penalty. But some applications demand special plates, which can increase total size nearer to that of a thyratron.

Life

Do the SCR's really have long life?

Theory suggests that semiconductors should last indefinitely, but available field tests are limited by the fact that

SCR's are only a few years old. Some designers have found that SCR's have failed within a few months. But laboratory tests show that the anticipated long life can be realized if the circuit is designed to make sure the SCR's operate only within their ratings. Of course, SCR's are new and require new design techniques, some of which may be unfamiliar.

Electrical limitations

What about limitations of SCR's in high ambient temperatures and with high supply potentials?

Electrical overloads and temperature variations can be handled by both SCR's and thyratrons. The controversy seems to be in the nature of the overloads allowed, yet manufacturers' catalogs for both SCR's and thyratrons clearly define the limits. In general, thyratrons have more voltage margin; SCR's can carry higher currents. Here are some of the specifics.

Thyratrons rated at 1500 v are practically immune to damage from voltage surges in ordinary circuits with potentials of 110, 220, 440, even 880 v. Some "corona" discharge might occur in 880-v circuits, but good design can eliminate the problem.

SCR's are lower-potential devices—500 v max. But careful circuit design can provide any desired safety margin. For instance—two SCR's in series double the voltage rating.

SCR's have higher current ratings—up to 70 amps, compared with 25 amps for the thyratron. And, contrary to what some designers have thought, SCR's can withstand overloads, in spite of their small mass. Provided they are limited to a few cycles, current overloads many times the rated value will not cause any dangerous temperature rise. High-speed fuses can provide extra safety.

Temperature affects SCR's more than it does thyratrons. Thyratron performance stays the same for temperature variations within normal ambient ratings (about −60 F to 170 F)—the cathode operates red hot. Derated, some can stand 400-F ambients—limitation is in the structural parts. Cold ambients make the device hard to "start."

SCR's are temperature-sensitive and current ratings are higher at the lower ambients. However, the total range of useful temperature is wide—from −80 to 260 F, and at the thyratron's limiting temperature of about 170 F, the SCR carries almost full rated current. The SCR can stand momentary over-temperatures at the junction considerably above its 300-F maximum storage temperature without failure.

Electrical failure of an SCR, if it occurs, is likely to be sudden. Thyratrons can also fail suddenly if overloaded or abused, but are more likely to fail gradually. A new thyratron offered by Reliance Electric (AIEE Paper CP 61-371) has a neon-gas indicator sealed with the xenon inside the evacuated tube; it glows a distinct red to warn of impending failure several hundred hours in advance. However, this glow, caused by ionization of the neon, does not occur until there is a 20-v loss through the tube, about double the loss in a new tube.

Circuit-breaking ability

Can controlled rectifiers be used as breakers?

Thyratrons and SCR's can both be used to shut off current in a circuit under certain circumstances. However, in most applications mechanical contactors are required because they offer positive shutoff.

Operating characteristics

Aren't many of the SCR's advantages of secondary importance?

It depends on the application. The thyratron has more voltage drop, requires a cathode heater, takes longer to warm up, and needs regulated voltage for its cathode. Where all these have little effect on performance, the choice obviously should be based on cost or other factors. For example, losses in the thyratron are only part of the over-all system losses, and unless voltage is low, are of little consequence. But at low voltages, efficiency of the SCR becomes important. On the other hand, where high-voltage surges are likely, the thyratron's higher voltage rating allows greater design flexibility.

The same is true of warmup. If the 6-sec warmup (for a 1-amp thyratron) and over half a minute for larger ratings are acceptable, then the SCR's instant startup if of little added value.

As for thyratron cathode-voltage regulation, ±5% regulation is adequate for normal circuits; close regulation (±2%) will give even longer life.

Waveform

Is the SCR's waveform really any smoother than that of a thyratron?

There is no simple answer, but this much seems sure: The smoothness of the waveform of either device depends on the load; and if there is any difference between the two, this difference more than likely is too small to affect over-all performance of the system.

Cost

What about the higher cost of SCR's?

It's true thyratrons cost less than SCR's now, but the gap is narrowing continuously. It is the opinion of most engineers that SCR's will soon compete in cost as they do now in performance.

ACKNOWLEDGMENTS

Our thanks to these electronic engineers and executives for their cooperation in discussing the SCR-vs-thyratron controversy and giving revealing comments on both sides of the argument: A J Humphrey, development engineer, Reliance Electric and Engineering Co; A L Di Vinuti, applications engineer, Transitron Electronic Corp; E K Smith, exec v-p, Electronics Inc; J H Hutchings, president, National Electronics Inc; B Berman, chief engineer, ACF Industries Inc.

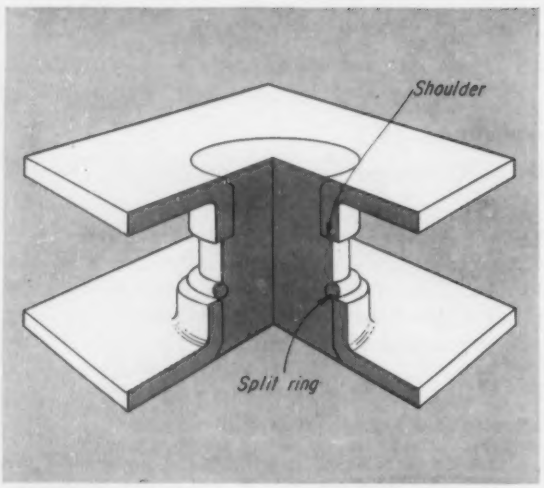
EDITOR'S NOTE: Here is a summary of the previous article on controlled rectifiers referred to in this issue:

SCR's vs Thyratrons, Jan 2 '61, p 29—Lists author-user Berman's opinions on why the new SCR is superior to the thyratron. Article covers these aspects: size, mechanical strength, electrical properties, operating temperature, startup, shutoff, special circuits. Included is a complete list of earlier articles related to this topic.

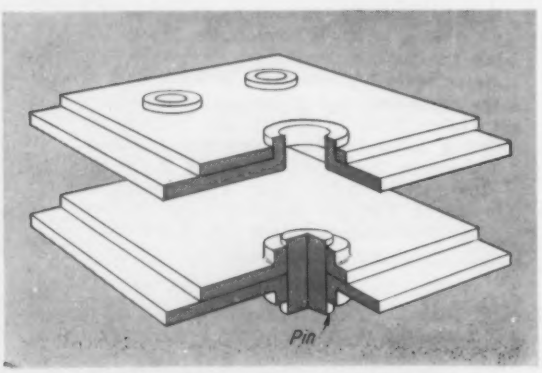
FLANGE DESIGN—7 VERSIONS

Here's how collared, extruded or dimpled holes solve many problems commonly found when working with sheetmetal.

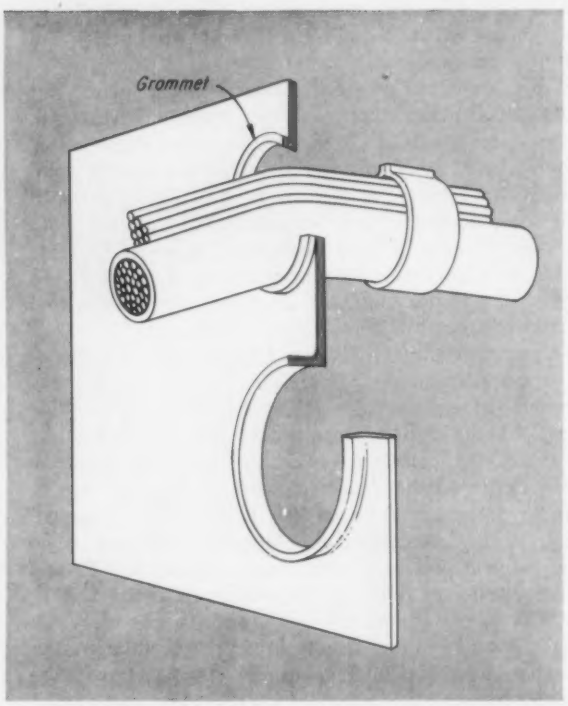
FEDERICO STRASSER
Mankowitz & Strasser
Santiago, Chile



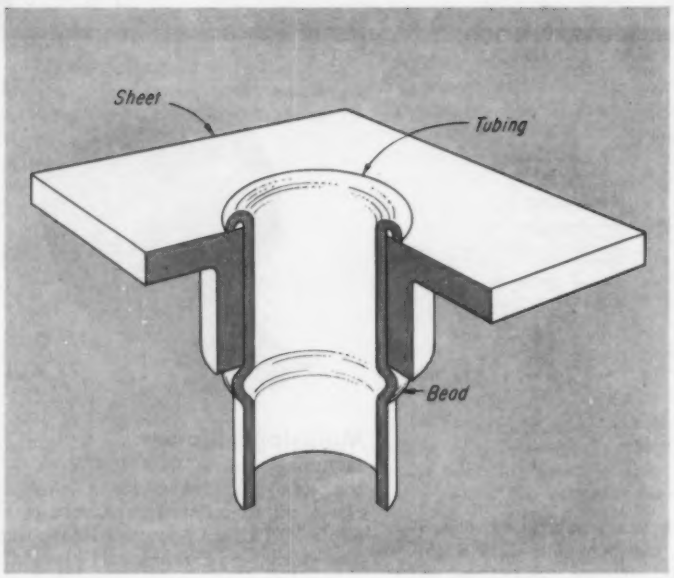
1. SHAFT joins to sheetmetal through flanged hole. Shoulder jams against flange, while end of shaft is riveted over into chamfered opening. Split ring in slot around shaft eliminates need to reduce end of shaft to make a shoulder.



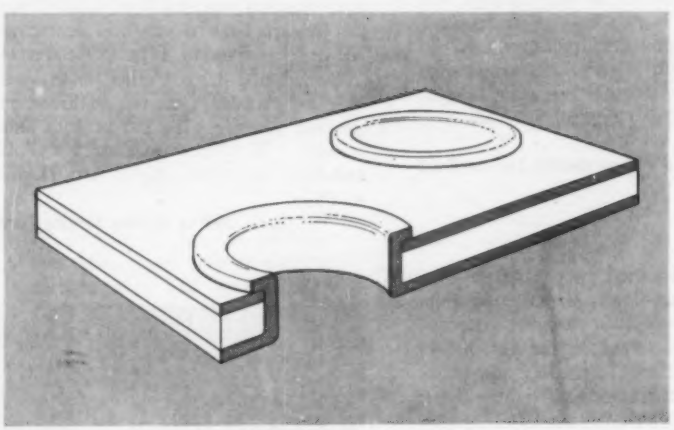
2. LOCATING-FLANGE on one sheet fits into plain hole in other sheet to position sheets accurately relative to each other. Dowel pin positions sheets when both have flanged holes.



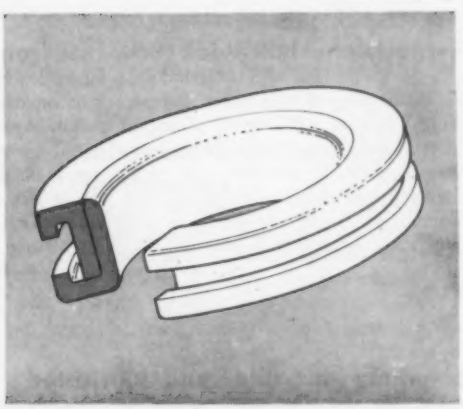
3. WIRING slides through grommet formed by bending over flange. Smooth sides of hole will not cut insulation. Also, flange around lightening hole gives stiffening to the panel.



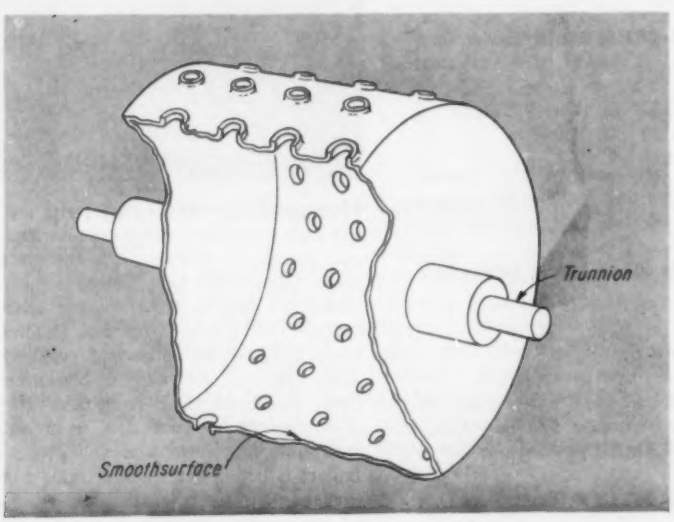
4. TUBING in flanged hole makes firm joint. Bead under flange and flared end provide seal and hold the tubing.



5. LIP on flange holds two sheets together. Here, asbestos sandwich forms a gasket.

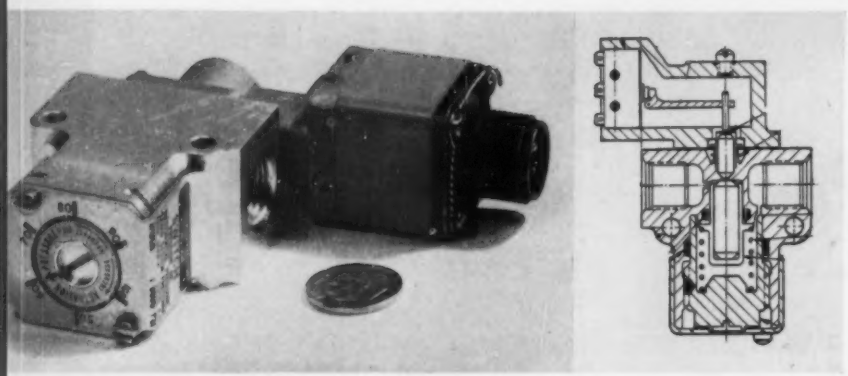


6. FEMALE GAGE is one flanged hole inside another. The inside piece is a press fit in the outer one or is welded to it.



7. DRUM for laundry or dry-cleaning machine must have holes for flow of water or solvent. At the same time, the inside surface has to be smooth so cloth and buttons won't catch. Flanged holes are the answer.

SIGNIFICANT COMPONENTS MATERIALS, PROCESSES



Pressure and differential switches . . .

cover pressure range from 15 to 200 psid and withstand system pressures or overpressures up to 5000 psi. When used as differential-pressure switches, units show actuation pressures which are independent of absolute working pressure. Switch set to actuate at 30 psid will do so with 30 psig upstream and zero psig downstream and will function equally well with 3000 psig upstream and 2970 psig downstream. Units operate by means of spring-biased magnets on which differential pressures act. In each switch, electrical mechanism is isolated from fluid and magnetic detent prevents "dither" when switch is vibrated near its actuation point. Normal operating temperature range is −65 to 160 F. Delivery in 6 to 7 wk. **Pall Corp, 30 Sea Cliff Ave, Glen Cove, NY.**

Circle 300 on Reader Service Card

Polypropylene has wide flow-rate range . . .

of 4.5 to 18 dg/min at 446 F and 2.16 kg load. Higher flow rate makes possible injection-molding of large parts that cannot be molded with lower flow-rate materials. Also said to have wide variety of impact-resistant formulas. Supplied in ⅛-in. pellets in natural and colors. Standard items are priced from 65¢ to 69¢ per lb in quantities of less than 200 lb and from 42¢ to 46¢ per lb in quantities of 22,000 lb or more. Colors and special items are priced from 78¢ to 82¢ per lb in 200 to 499-lb quantities and from 51¢ to 55¢ per lb in 22,000-lb or more quantities. **Eastman Chemical Products Inc, Kingsport, Tenn.**

Circle 301 on Reader Service Card

Compressed-air filter and lubricator . . .

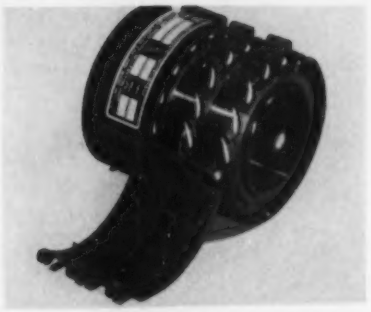
has zinc-alloy bowl equipped with sight level-indicating gage made of heat resistant glass tubing. Tube is protected from accidental impact by thin metal strip running full length in front of it. Level of content in bowl is visible full 230°, allowing it to be seen from behind. **Wilkerson Corp, Englewood, Colo.**

Circle 302 on Reader Service Card

Heavy-duty pushbutton switch . . .

has SPDT circuitry and is rated 5 amp at 125/250 v ac; 2.5 amp at 30 v dc inductive; or 4 amp at 30 v dc resistive. Switch offers 0.250 min overtravel, 4-oz min release force and movement differential of 0.004 max. **Control Switch Div, Controls Co of America, 1420 Delmar Dr, Folcroft, Penna.**

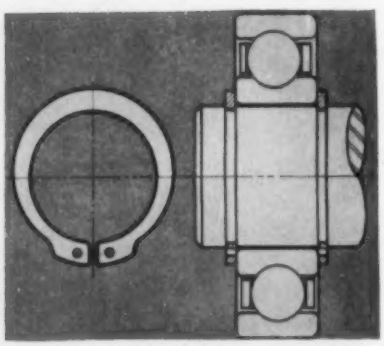
Circle 303 on Reader Service Card



Multistage blower . . .

measuring 3 in. in dia x 3 in. long, uses compressor-staging principles to deliver 39 cfm of air against system resistance of 14 in. water. Originally designed for use with heat exchangers, transistor cold plates and crowded electronics enclosures. With its low specified speed (N_s=15,000), unit can replace large radial-wheel centrifugal blowers rated up to ¼ hp. Operates on 200 v ac, 400 dc, but other power variations are available. One, two or three compression stages can be mounted in same housing. Prototypes from stock. **Globe Industries Inc, 1784 Stanley Ave, Dayton 4, Ohio.**

Circle 304 on Reader Service Card



Heavy-duty retaining ring . . .

has high thrust-load and impact-resistance and provides a shoulder high enough to retain parts with large corner radii or chamfers. Can be used without spacer washers to secure light and medium series ball, tapered roller and cylindrical roller bearings, retaining the bearings to their max load-rating capacities. High load capacity permits ring to replace heavy-duty nuts, machined shoulders and bulkier fastening devices in securing components on shafts, axles and similar

structural members. Repeated expansion and contraction of the ring for assembly and disassembly reportedly causes only negligible change in free diameter or circularity. Unit is thicker than basic external-type retraining ring and has increased section height. Wider lugs extend farther into ring's body, providing uniform load distribution against retained part and compensating for section height. Available in 11 sizes for shafts ranging in dia from 0.473 to 2 in. Allowable thrust loads for hard grooves (cut in material with tensile yield strength of 150,000 psi) ranges from 2300 lbs for 0.473-in. ring to 29,400 lb for 2-in. ring. **Waldes Kohinoor Inc, 47-16 Austel Pl, Long Island City 1, NY.**

Circle 305 on Reader Service Card

Machine swages . . .

square, rectangular, tapered and formed cross-sections; points; wedges; and other end contours. Finished parts, such as harrow spikes, auger-bit shanks, soldering-iron tips and screwdrivers, can be produced from entry rounds, squares or rectangles in one operation, with parts reportedly free from fins or flashing. Points rectangular shapes prior to drawing and reduces squares and rectangles to smaller sizes of same shapes. **Fenn Mfg Co, Fenn Rd, Newington, Conn.**

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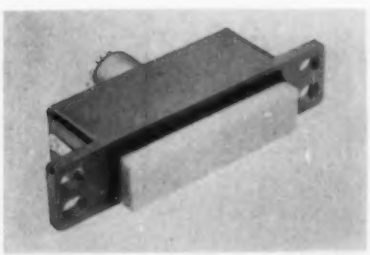


Bar switchlight . . .

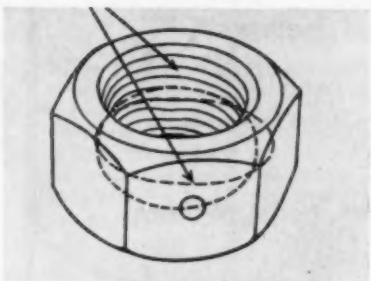
has twin ball bearing actuator guides which make it possible to depress plunger at any point on lens surface without tilting or binding, using just fingertip pressure. Plunger travel is approx $\frac{1}{8}$ in. Rated at 28 v dc, 2-amp resistive, switch is available as 1, 2 or 3PDT or 2, 3, 4, or 6PST "billboard"-type, panel-mounted unit. Dual independent lamp circuit is said to provide even distribution of light across entire surface of 3 x $\frac{3}{4}$-in. molded lens. Lens, available in red, white, green and yellow, snaps in and can be rebulbed from front. From stock. **Pendar Inc, 14744 Arminta St, Van Nuys, Calif.**

Circle 307 on Reader Service Card

Process heater . . .

is capable of stable burning operations at temperatures from 150 to 5600 F and pressures to 1000 psi. All-metal, air- or water-cooled unit is essentially a step-type burner. Air, oxygen or mixture is introduced through inlet duct and flows without restriction through a step section where a variety of fuels can be injected. Uses a high-velocity combustion technique to obtain high thermal capacity in a small combustion unit. Designed for 3,600,000 to 1,980,000,000 btu/hr. duty. Suitable for hi-temp materials testing, intermittent steam generation, partial oxidation reactors, sound generation, air heating, etc. **Marquardt Corp, 16555 Saticoy St, Van Nuys, Calif.**

Circle 308 on Reader Service Card



Double chamfered locknut . . .

can be applied from either side and uses two locking principles: it is ovalized to give 180° spring and threads are deflected at point of lock. Thus, nut can be locked in any position. Locking device is in body of nut for greater locking power when nut is mounted flush with end of bolt or when all threads are not used. Available in size #5 through 1$\frac{1}{4}$ in. **MacLean-Fogg Lock Nut Co, 5535 N Wolcott Ave, Chicago 40.**

Circle 309 on Reader Service Card

Corrosion-resistant stainless . . .

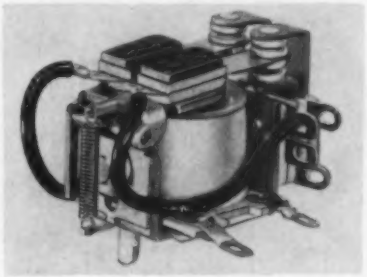
steel said to have even higher corrosion resistance than Type 430 is available at no increase in price. Designated type 433, alloy has additions of molybdenum and copper to counteract effects of salt and other road de-icing and road-clearing materials. Supplied in same gages and widths as standard 430. Is rolled on same equipment and can be bright annealed as in 430. **Allegheny Ludlum Steel Corp, Oliver Bldg, Pittsburgh 22.**

Circle 310 on Reader Service Card

Rigid polyurethane foam . . .

for thermal insulation has approx same density as polystyrene foam (from 1.6 to 2 lb per cu ft) but twice the insulating value. Former has K factor averaging 0.14, compared with polystyrene foam's 0.28. Effective insulating range is from —300 to 200 F. Material resists most solvents and is reported to have good acid resistance and high resistance to gasoline and petrochemicals. Available in wide variety of sizes, including 24 x 36, 12 x 36, 12 x 72, and 24 x 72 in. Thicknesses range from $\frac{1}{2}$ to 15 in. **Pittsburgh Corning Corp, 1 Gateway Center, Pittsburgh 22.**

Circle 311 on Reader Service Card



Ac-dc power relay . . .

has pin-type armature hinge with centerless ground stainless steel pin and precision reamed bearing surfaces—said to allow adjustment stability through long service life with low friction and positive contact effectiveness. Furnished with DPDT or SPDT, 15-amp, heavy duty silver alloy contacts for ac and dc operation. From stock with DPDT contacts for 6, 12, 24 and 115 v ac and dc. Priced at $5.90 to $6.40 each. **Magnecraft Electric Co, 3350Y W Grand Ave, Chicago 51.**

Circle 312 on Reader Service Card

Miniature liquid-in-glass thermostat . . .

directly switches 1-, 4.7-, 10-amp or larger normally open or normally closed current loads without external relays or amplifiers. Handles output voltages up to 400 v and frequencies from 25 to 1000 cps. Achieves internal power gains of 1 million, although only 85 microamps pass through mercury column to switch 1-amp current. Unit is available in 0.4-in. dia x 1$\frac{1}{2}$-in. long size for ac operation (slightly higher for dc). **Precision Thermometer & Instrument Co, 1434 Brandywine St, Philadelphia 30.**

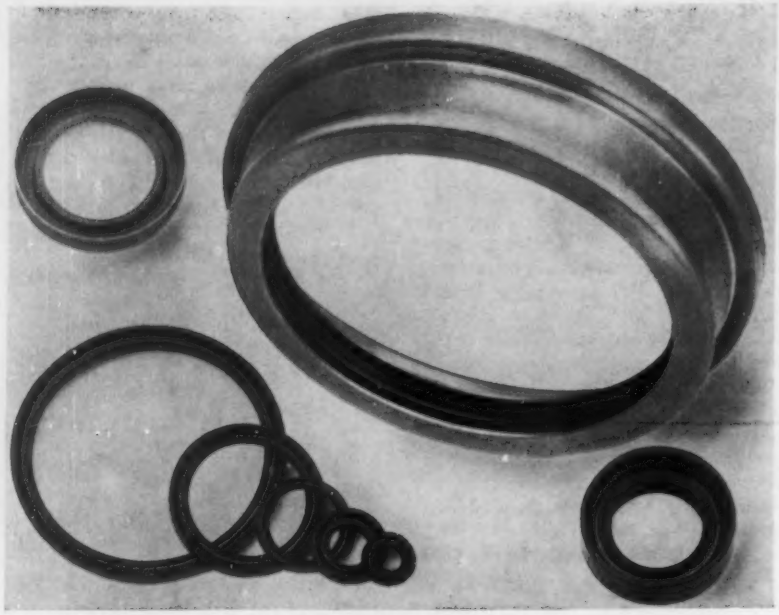
Circle 313 on Reader Service Card

Urethane elastomer . . .

supplied in granular form, is said to cut part-forming time from hours to seconds. Permits mass production of urethane elastomer items by injection and transfer

continued on page 84

CUSTOM SHAFT TYPE SEALS



- **COMPLETE SERVICE FOR ALL SEAL PROBLEMS**
- **DESIGN RECOMMENDATIONS**
  Plain, Metal Clad, Spring Tension, Lip Configuration
- **MATERIAL SELECTION**
  Nitrile, Neoprene, Silicones, Viton, Fluorel, Urethane Elastomers
- **EVALUATION BY SIMULATED LABORATORY TESTING**
  *By Sealrater Endurance Tester
- **PRODUCTION AND INSPECTION UNDER THE RIGID QUALITY CONTROL OF OUR PRECISION-MOLDED RUBBER FACILITIES**
  *Sealector . . . Air Gauges . . . For Lip Diameter and Lip Pressures

* Research Laboratory Division, General Motor Corp.

As producers of custom molded rubber parts exclusively, we seek special problems only, and do not offer compromise standard seals for the solution. The services of our Engineering and Technical Staffs are always available for study of your particular application.

Precision-Molded Acushnet *Rubber Products*

ACUSHNET PROCESS COMPANY
NEW BEDFORD, MASSACHUSETTS

Address all communications to 768 Belleville Ave., New Bedford, Mass.

molding or extrusion. Can be molded with existing equipment, attaining properties said to be identical to cast urethane elastomers. Hardness values range from soft, highly plasticized vinyl plastic to hard molded nylon. Properties that can be specified range from elongation of 500 to 800% with durometer hardness of 60-65 Shore A up to 250% elongation at 65 Shore D hardness. **Mobay Chemical Co, Pittsburgh 5.**

Circle 314 on Reader Service Card

Decade-counter tube . . .
operates without interstage amplifier. Indication is by orange-red glow discharge which is viewed through dome of tube envelope at end of electrodes. Cold cathode, gas-filled tube requires no heating power or warmup time. Is inoperative during standby periods and free from photoelectric effects with ignition characteristics remaining constant during daylight and darkness. Operates at speeds up to 4 kc. **Amperex Electronic Corp, Semiconductor & Special Purpose Tube Div, 230 Duffy Ave, Hicksville, LI, NY.**

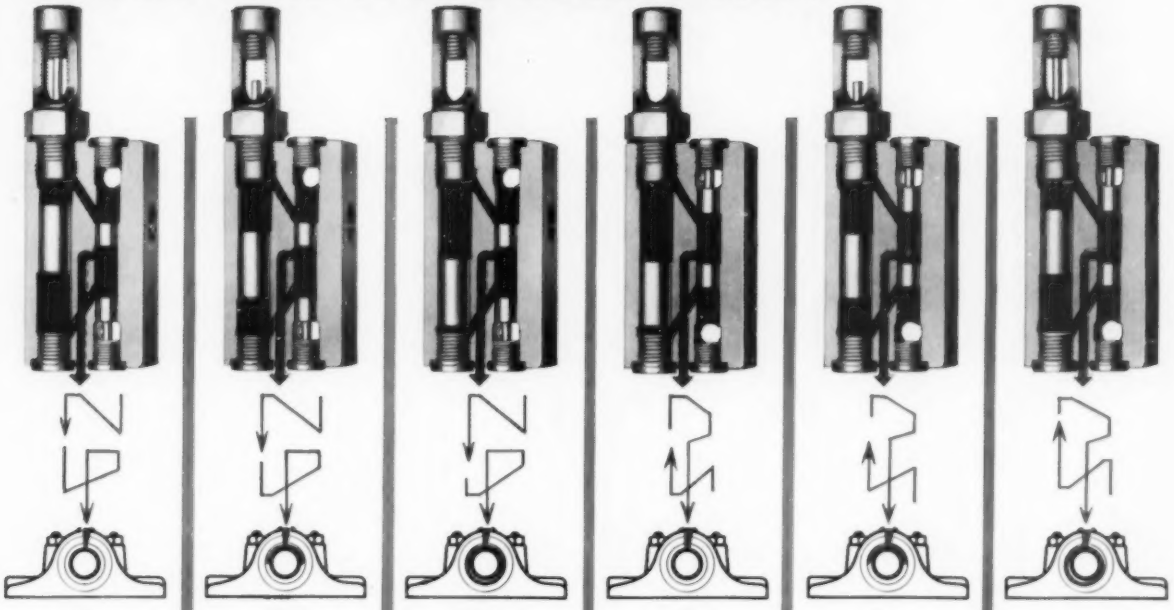
Circle 315 on Reader Service Card

Digital time and frequency meter . . .
uses four of its eight decades for storage and continuous display, while remaining four counts continuously. At end of each counting interval, total accumulated by counting decades is transferred auto-

continued on page 89

Here's design simplicity

Farval's Time-Tested Dualine Valve



1

(In red) Lubricant under hydraulic pressure enters inlet at top right — pushing slide valve down and filling upper diagonal passage and chamber above main piston.

(In blue) By this movement, lower head of piston slide valve uncovers lower diagonal passage leading from the main piston chamber. This chamber is full of lubricant from the previous operation.

2

(In red) Lubricant under pressure entering through upper inlet port and into main chamber continues to force main piston downward —

(In blue) discharging lubricant through lower diagonal passage to vertical passage and to outlet port leading to bearing.

3

(In red) Lubricant entering from upper port has now forced the main piston to end of its stroke, and thus the full measured charge below piston has been delivered to the bearing.

Note that indicator stem has also moved down, indicating main piston has reached end of its stroke, and that no more lubricant will be delivered from this operation.

4

(In blue) Lubricant under hydraulic pressure enters inlet at bottom right — pushing slide valve up and filling lower diagonal passage and chamber below main piston.

(In red) By this movement, upper head of piston slide valve uncovers upper diagonal passage leading from the main piston chamber. This chamber is full of lubricant from the previous operation.

5

(In blue) Lubricant under pressure entering through lower inlet port and into main chamber continues to force main piston upward —

(In red) discharging lubricant through upper diagonal passage to vertical passage and to outlet port leading to the bearing.

6

(In blue) Lubricant continuing to enter under pressure from the lower port has now forced main piston to the end of its stroke, and thus the full measured charge above piston has been delivered to the bearing.

Indicator has reached its top limit, showing the job is done.

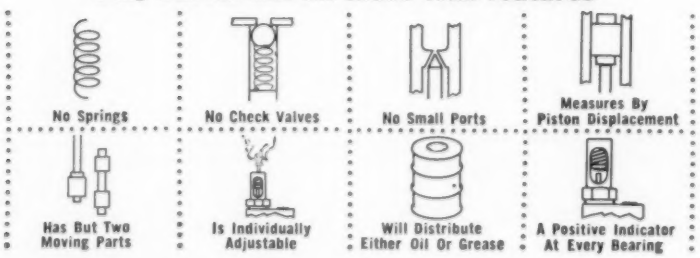
That's why *FARVAL DUALINE* is today's most dependable, positive system of centralized lubrication

Write for free copy of Bulletin 26-T — it gives the complete Farval "Story".

Farval Division
Eaton Manufacturing Company
3279 E. 80th St. • Cleveland 4, O.

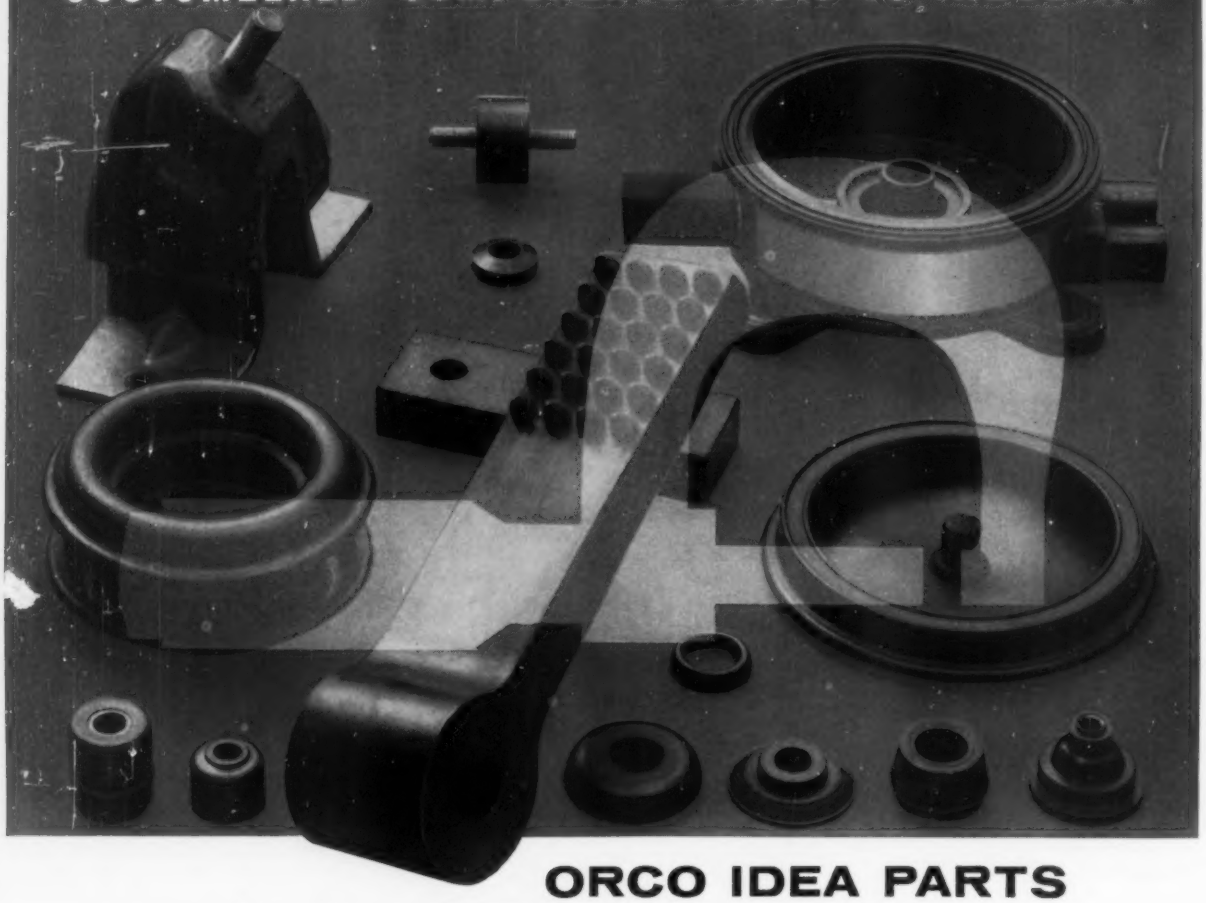
Farval Studies in Centralized Lubrication No. 255

Only Farval has all these vital features


No Springs
No Check Valves
No Small Ports
Measures By Piston Displacement
Has But Two Moving Parts
Is Individually Adjustable
Will Distribute Either Oil Or Grease
A Positive Indicator At Every Bearing

OHIO RUBBER

"CUSTOMEERED* COMPONENTS BASIC TO INDUSTRY"



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shape up OEM designs—profitably!

OHIO RUBBER IS THE GOOD SOURCE FOR THE OEM!

ACROSS THE BOARD in industry, ORCO IDEA PARTS offer the design engineer product quality evolved from Ohio Rubber's years of experience in supplying "Customeered"* components for outstanding original equipment manufacturers nationwide.

ORCO CUSTOMEERING* is geared to cut production costs—to deliver a better part. And it goes to work for you as soon as performance requirements are checked, a materials recipe is formulated, expense-shaving design modifications, if necessary, suggested. The full scope of ORCO integrated design, research and practical ingenuity in custom-manufacture of rubber, synthetic rubber, silicone rubber, polyurethane, and flexible vinyl components is focused on your component.

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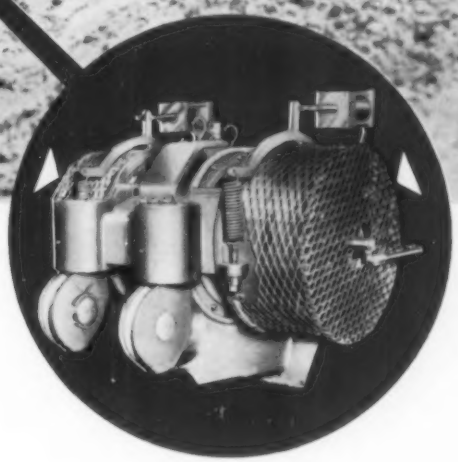
A DIVISION OF THE EAGLE PICHER COMPANY

EAGLE PICHER

CIRCLE 87 ON READER SERVICE CARD→

WICHITA CLUTCHES OFFER COMPACT, TROUBLE-FREE CLUTCHING POWER FOR RUGGED EARTHMOVERS



For dependable power control this Curtiss-Wright Scraper is Wichita equipped.

On this Curtiss-Wright 26-yard Self-Propelled Scraper two Wichita Clutches are used to clutch the double-drum, air-actuated cable control unit. On this and many other earth-moving machines Wichita is proving dependable on the job.

For any clutching or braking problem . . . the tougher the better . . . you can count on Wichita. Call in a Wichita Engineer today!

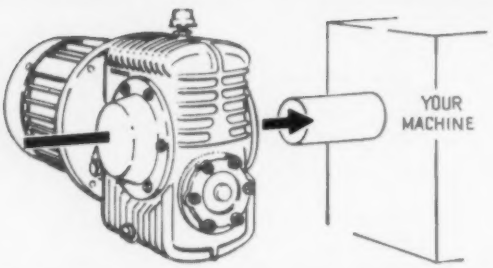
For any difficult clutching or braking problem . . .

CONTACT YOUR NEAREST WICHITA ENGINEER

Clutch & Control Engineering Co., Livonia, Mich.
Fremont & Lewis, Inc., Cincinnati, Ohio
W. G. Kerr Company, Pittsburgh, Pa.
Smith-Keser & Co., Avon, Conn., Philadelphia 44, Pa., and New York, N. Y.
Frank W. Yarline Co., Chicago, Illinois
Larry W. McDowell, Long Beach, California
Andrew T. Lobel, Denver, Colorado
Robert R. King Co., Cleveland, Ohio
Norman Williams, Houston, Texas
Allied Transmission Equipment Co., Kansas City 8, Missouri
Donald E. Harman, Dallas, Texas
C. Arthur Weaver, Richmond, Virginia
Malcolm S. Cone, Memphis, Tennessee
Dominion Power Press Equipment, Ltd., Burlington, Ontario, Canada
R. E. Kunz, Seattle 4, Wash.
Norman Rupp Co., Portland 4, Ore.
Bates Sales Co., St. Louis 1, Mo.

WICHITA Clutch COMPANY, INC.
WICHITA FALLS, TEXAS, U.S.A.

CONE-DRIVE GEARMOTORS for "PLUG-IN" POWER

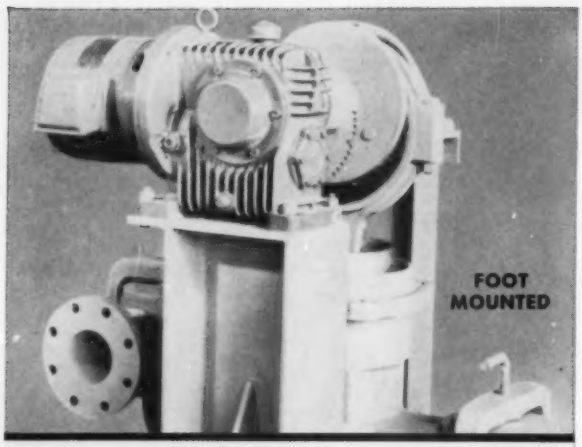


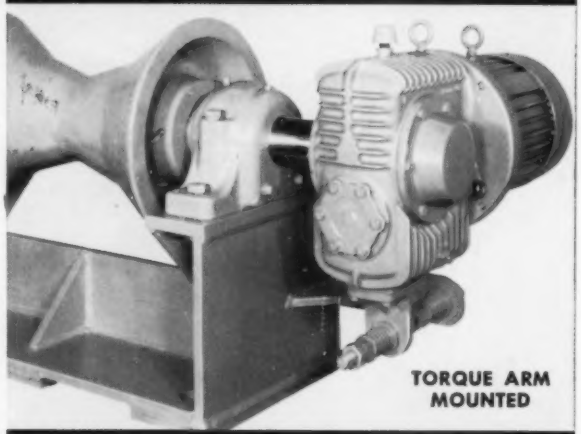
Hollow-Shaft Speed Reducer-Motor forms complete power transmission package . . .

With the compact, right-angle Cone-Drive gearmotor the machine designer can make use of an integral drive package of nearly any required speed and horsepower. Twenty-seven standard output speeds from 7.3 to 525 RPM (with 1750 RPM motor) are available in models from ¼ to 40 horsepower. Gearmotors can be specified with hollow shaft for mounting in any position, ready to "plug-in". You can use this integrated power package to provide a simple, clean installation on your machine . . . no pulleys, belts, sheaves, bed plates, couplings, etc.

Electric motors are standard "D" flange type with slight shaft modification for driving helical primary reduction gears. Secondary reduction stage is a standard Cone-Drive double-enveloping worm gearset with maximum tooth engagement for greater load carrying capacity in smaller space.

Cone-Drive gearmotors are available for all AGMA service ratings. Call your Cone-Drive representative today or write for catalog #58 for complete specifications.





CONE-DRIVE GEARS
DIVISION MICHIGAN TOOL COMPANY
7171 E. McNichols Road Detroit 12, Michigan Telephone: TWinbrook 1-3111

matically in 100 microsec to storage and display decades. Counter reportedly performs properly even with tubes approaching half-dead state. Uses "hard-bottoming" multivibrator dividers that eliminate need for periodic adjustments of time-base circuits. Unit's frequency range is dc to 10 mc; period, 10 microsec to 10^7 sec; time interval, 1 microsec to 10^7 sec. Sensitivity is 0.25 v rms. Price range from $2,585 to $2,950. General Radio Co, West Concord, Mass.

Circle 316 on Reader Service Card

Miniature contactor . . . is 3PDT relay rated 50 amp at 115/208 v, 400 c. Measuring less than half the size of other 50-amp contactors, 12-oz unit is hermetically sealed in a can 2¾ in. dia x 2⅞ in. high. Operates in ambients of —85 to 248 F, under 20 g's to 2000 cps vibration and at 0 to 80,000 ft altitude. Hartman Electrical Mfg Co, 175 N Diamond St, Mansfield, Ohio.

Circle 317 on Reader Service Card

Light-indicator modules . . . for instrument and computer use, are self-contained and require only suitable external power supplies and trigger signals. Internal components are welded together and potted. Four of the line's modules (two for negative and two for positive logic) use transistor amplifiers and glow lamps and require high voltage supplies. Two other negative and positive logic

continued on page 90

One word explains the popularity of these switches...

Dependability!

Denison LOXSWITCH Limit Switches operate with the dependability of Old Faithful. Oil- and dust-tight features, superior electrical characteristics and mechanical design result in three to five times longer life than comparable switches.

L100W HEAVY DUTY LIMIT SWITCH

- 45 CIRCUIT ARRANGEMENTS.
- LONGEST CONTACT LIFE due to lowest impact of 2.5 grams and minimum "bounce".
- WATER-, DUST- AND OIL-TIGHT, NEMA 12.
- ONLY FOUR MOVING PARTS. Longer life, easier to maintain.
- 70° SAFETY OVERTRAVEL without use of extra springs or cams.
- OVER 150 LEVER STYLES.

MODEL M PRECISION LIMIT SWITCH

- LONG MECHANICAL LIFE nylon latch mechanism.
- 600 VOLT INDUSTRIAL CONTROL RATING.
- COMPLETELY ISOLATED CIRCUITS.
- 6° TRIP DIFFERENTIAL, 50° overtravel in both directions.
- PRECISION REPEATABILITY ± .001".
- WATER-, OIL-, DUST-TIGHT — NEMA 12.
- FULLY INTERCHANGEABLE with thousands of existing layouts.

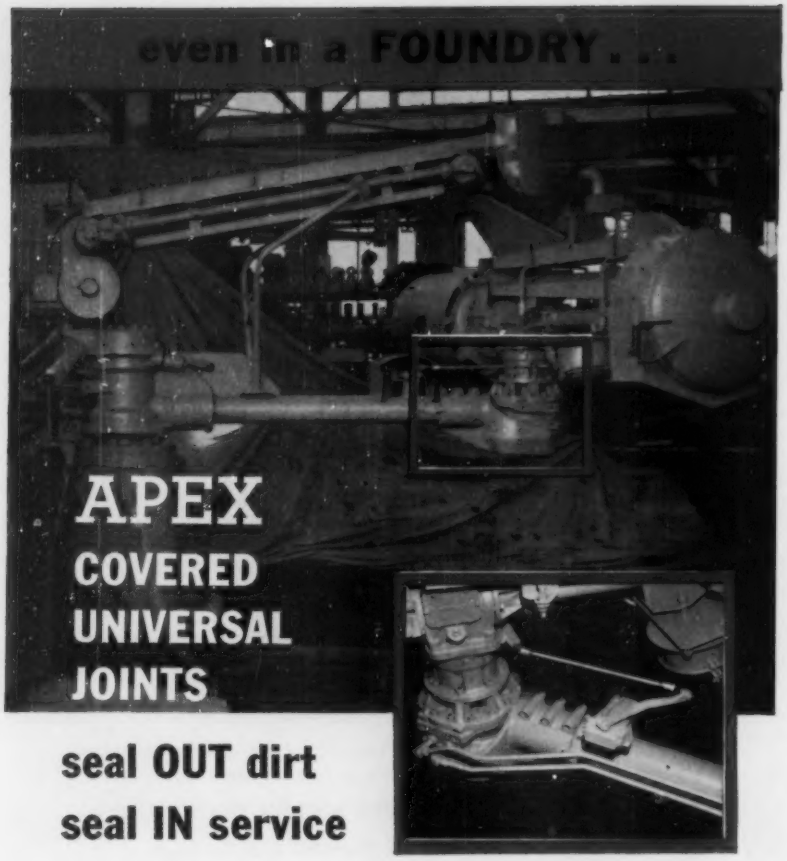
BOTH MODELS AVAILABLE WITH PLUG-IN CONVENIENCE

Write for literature describing our complete line.

Address R. B. DENISON MFG. CO., 386 Broadway, Bedford, Ohio

DENISON LOXSWITCH ®

Wire with **LOXSWITCH** *and you wire for good!*



seal OUT dirt
seal IN service

Apex covered universal joints are used at each end of the actuating levers, and at each end and the center of the walking beams on this machine for accurate, repetitive ramming of sand molds. PHOTOS COURTESY OF BEARDSLEY & PIPER, DIV. PETTIBONE MULLIKEN CORP.

Operating conditions encountered in foundries create special problems in designing equipment like the Beardsley & Piper Automatic Hydra-Slinger: every component must function perfectly under the most adverse conditions.

Only covered, pre-lubricated universal joints—an exclusive Apex development—can meet these operating requirements. The specially-compounded flexible cover protects the joint against abrasion, even permits operation in water, gases, corrosive liquids or extremes of temperature.

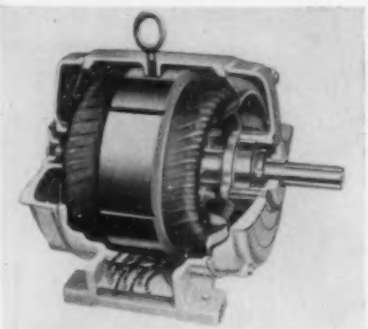
If your drive-line design problem is especially troublesome, Apex *covered* universal joints could be the answer. Write, on your company letterhead please, for Catalog 28.

THE
APEX
MACHINE & TOOL CO.
1042 South Patterson Blvd.
DAYTON 2, OHIO

Phantom view of APEX covered universal joint which operates efficiently in wet or dry, corrosive or abrasive atmospheres, and in extremes of temperatures.

devices use transistors and incandescent lamps. Both can be operated from low-voltage power supplies in typical transistor circuits. Another module employs filamentary thyratrons and is a turn ON, positive logic device that triggers in less than 10 microsec. Still another unit employs a cold cathode thyratron. Its neon red lamp is seven times the brilliance of nomal glow lamps. **Industrial Components Div, Raytheon Co, 55 Chapel St, Newton 58, Mass.**

Circle 318 on Reader Service Card



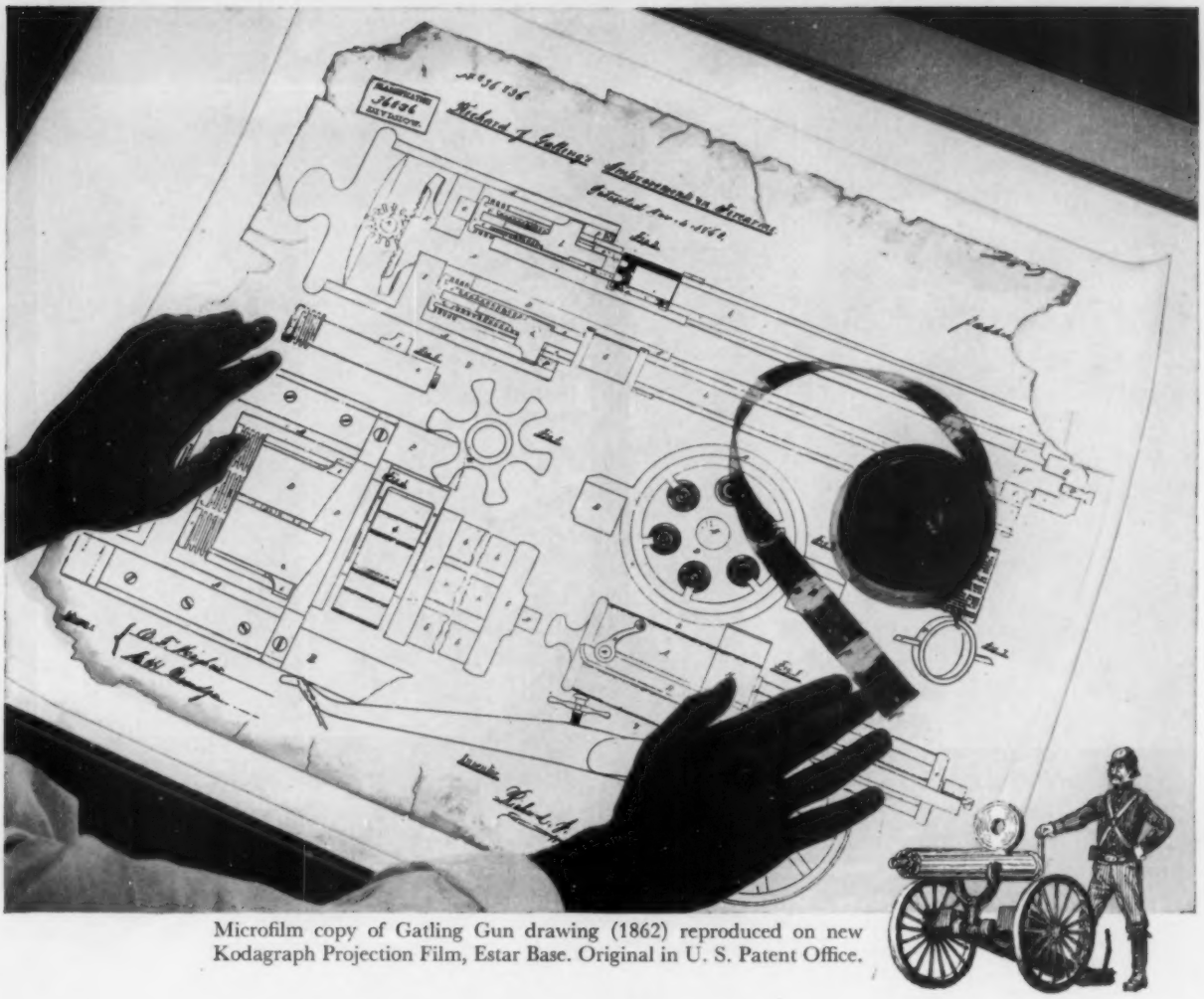
Ac induction motors . . . have encapsulated windings that permit operation over wide extremes and sudden changes of temperature. Encapsulating material is said to have high resiliency which allows it to withstand effects of airborne contaminants drawn into motor by ventilating air stream. Insulation supplied on open, dripproof motors, 445U frame sizes and smaller, 600 v and below. **Louis Allis Co, Dept P, 427 E Stewart St, Milwaukee 1.**

Circle 319 on Reader Service Card

Two relays, overload protector recently introduced, include: SPDT impulse relay which alternately transfers from one switch position to another on a series of successive similar pulses, operates on 1000 microjoules and has vibration immunity in order of 30 g's to 2000 cps; general purpose relay which switches loads up to 10 amp and has dc sensitivities of 200 mw to 1 w and ac sensitivities of 0.5 to 3.5 v-amp; and overload interrupter which protects rectifiers and transistors from destruction by dc overload currents as high as 5 amp and operates in 0.5 to 5 ms. Sample quantities of all three delivered in 3 to 4 wk. Impulse relay is priced from $30 to $40; general purpose relay, from $7 to $8; and overload interrupter, from $20 to $30. **Sigma Instruments Inc, 170 Pearl St, South Braintree 85, Mass.**

Circle 320 on Reader Service Card

continued on page 93



Microfilm copy of Gatling Gun drawing (1862) reproduced on new Kodagraph Projection Film, Estar Base. Original in U. S. Patent Office.

Big Blowup from microfilm!

New Kodagraph Projection Film, Estar Base, produces change-in-scale intermediates that will stand up under the heaviest use in drafting room or print-room.

Blowups from microfilm—or reductions of drawings and maps—are remarkably sharp and clean on a whiter base that has a "built-in" longer life.

Production is easy. This new high-contrast, quick-processing film can be exposed in enlarger, projection printer, process camera . . . and handled with "1A" safelight. Wide latitude all but ends make-overs.

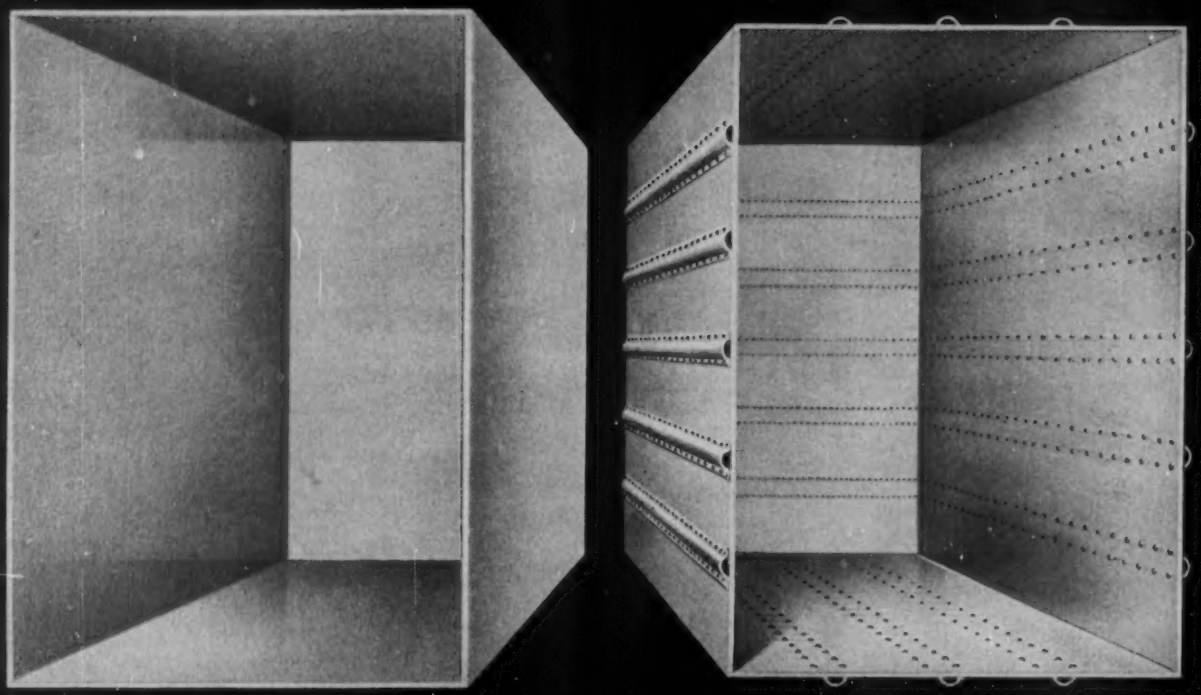
See this versatile new Kodagraph Film—and the others in the new *Estar Base line:* Kodagraph Contact Film; Kodagraph Autopositive Film.

All combine reliable Kodak emulsions on the new Estar Base—highly translucent, durable, and dimensionally stable, with excellent matte surface on both sides for easy drafting. Available in standard drawing sheet sizes and in rolls up to 52 inches wide. Call your local Kodagraph Dealer, or write Eastman Kodak Company, Graphic Reproduction Division, Rochester 4, N. Y.

NEW!
Kodagraph
REPRODUCTION FILMS
for better line-for-line reproduction

Kodak
TRADEMARK

CIRCLE 91 ON READER SERVICE CARD



NO-RIB

RIBBED

Thick-gauge magnesium sheet is so rigid that time-consuming rib stiffeners and fasteners are eliminated. Yet the magnesium panels are light and strong, resist dents and punctures better than thin-skinned ribbed construction.

WHICH HIGH-STRENGTH DESIGN WEIGHS LESS... COSTS LESS TO BUILD?

Magnesium no-rib, of course. By increasing the sheet thickness slightly, designers of containers and vehicle bodies get a tremendous boost in rigidity, thus can eliminate stiffening ribs. And since magnesium is the lightest structural metal, the resulting unit weighs less than conventionally-designed structures using other metals. (No-rib design in other metals introduces a severe weight penalty.) Magnesium no-rib structures are smooth-walled, minimize crevices for water seepage, have greater cubic capacity pound-for-pound than ribbed units. For detailed information on using magnesium no-rib construction for fabricated units of all types, write THE DOW METAL PRODUCTS COMPANY, Merchandising Department 1108DZ3-20, Midland, Michigan.

DOW

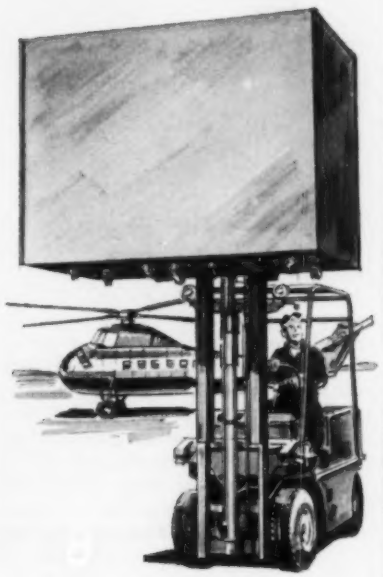
THE DOW METAL PRODUCTS COMPANY

Division of The Dow Chemical Company

CIRCLE 92 ON READER SERVICE CARD

DOW

HOW MAGNESIUM NO-RIB DESIGN CUTS CONTAINER COSTS AND WEIGHT



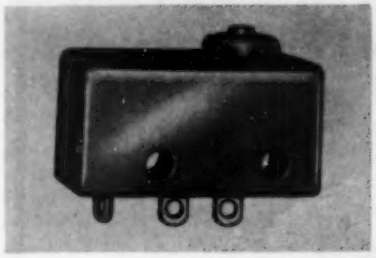
Cargo containers can be made both strong and light . . . and at less cost . . . with magnesium no-rib design. Fabricated from stiff sheets of lightweight magnesium, container walls need no stiffening ribs or supports.

No-rib design eliminates costly, time-consuming installation of ribs and fasteners . . . provides strong, dent-resistant walls that are smooth inside and out . . . produces economical containers that, pound-for-pound, have greater cubic capacity than ribbed containers of any other metal.

Dow magnesium sheet alloy ZE10A is ideal for no-rib construction. It provides high welded-joint strength and *needs no stress relief* after welding. For equipment handling and cargo containers, storage bins, vehicle bodies, magnesium no-rib construction offers maximum strength at lightest weight . . . and savings in construction time and costs!

DOW

THE DOW METAL PRODUCTS COMPANY
Division of The Dow Chemical Company
Midland, Michigan



Miniature T switch . . .

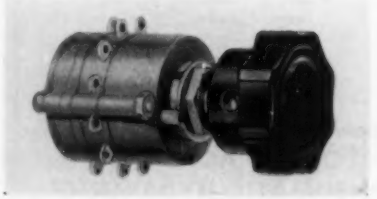
is hermetically sealed in steel case. Unit is SPDT switch with following electrical rating: 7.5 amp at 125/250 v ac, 60 c inductive and resistive; 3 amp at 125/250 v ac, 60 c motor; 7.5 amp at 28 v dc resistive; 2.5 amp at 28 v dc inductive; and 3 amp at 28 v dc motor. Measuring 0.787 in. long, switch weighs 7 gm and has pretravel of 0.012, movement differential of 0.003 and min operating force of 550 gm. **Control Switch Div, Controls Co of America, 1420 Delmar Dr, Folcroft, Penna.**

Circle 321 on Reader Service Card

Multicolor ribbon cable . . .

consists of 2 to 20 plastic insulated wires bonded together to form flat cable. Can be furnished with conductors all of one color or each of a different color. Available in sizes Nos. 28 through 10, up to 1 in. wide. **Westwood Cable Corp, 3440 Overland Ave, Los Angeles 34.**

Circle 322 on Reader Service Card



Molded 1-in. dia tap switch

is available with up to eight decks, up to 12 positions per deck and adjustable stops if lower number of steps is required. Rated 1200 v rms, 2000 v dc, 5 amp (carrying), 115 v. Has insulating resistance of 100 megohm min at 500 v dc and contact resistance of 6-10 milliohm. Life is 1.5 to 2 million revolutions within temperature range of −85 to 176 F. **Tech Laboratories Inc, 46 Bergen & Edsell Blvds, Palisades Park, NJ.**

Circle 323 on Reader Service Card

Bar-stock ball valve . . .

has two Teflon seats that seal flow in both directions. Rated at 600 wog with 1000 psi test, valve is available in carbon

continued on page 94

COMPACT AiResearch 60 cycle Actuators *for ground use . . .*

Inexpensive, lightweight 60 cycle motor driven actuators with integral magnetic brakes* are now being manufactured by AiResearch for ground radar, ground support and shipboard use.

Unequalled in 60 cycle performance, these extremely compact, lightweight actuators range from fractional hp motor size up to any desired hp in single phase, two phase and three phase design for a wide variety of applications.

The above-pictured actuator is used in a ground radar system. It is driven by a single phase 60 cycle ac fractional hp electric motor and can be furnished with a feedback potentiometer for use in servo applications. The entire unit weighs only 2½ lb. and is rated at 200 lb. operating load.

OTHER ELECTROMECHANICAL COMPONENTS AND SYSTEMS

A C and D C Motors, Generators and Controls • Static Inverters and Converters • Linear and Rotary Actuators • Power Servos • Hoists • Temperature and Positioning Controls • Sensors • Programmers • Missile Launchers • Radar Positioners • Power Supplies • Williamsgrip Connectors

Your inquiries are invited.

** patented 60 cycle operated magnetic brake*

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AiResearch Manufacturing Division

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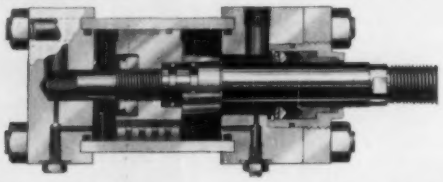
J. I. C. Interchangeable SQUARELINE Series features a Metal Rod Scraper *plus* a Rod Wiper in a quick change Cartridge—*Double protection* against chips, dirt, damage. Unitized cartridge rod bearing . . . easy removal and replacement . . . no cylinder disassembly necessary!

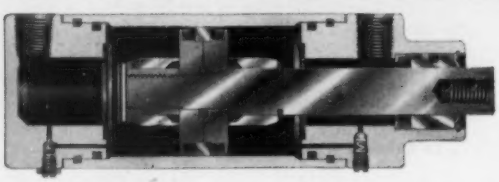


SQUARELINE 2000-3000 PSI HYDRAULIC

- 1½" to 12" bore
- 100% JIC interchangeable
- True cushion-automatic concentric alignment
- Positive piston locknut design
- Delivery from stock!

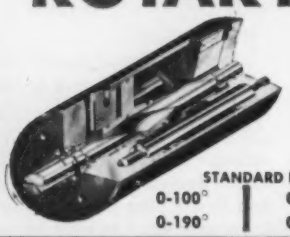
THE COMPLETE LINE CARTER FLUID POWER

ROUNDLINE AIR-HYDRAULIC



- Space saving designs! Light weight!
- Full 1 to 1 Meehanite cartridge rod bearing.
- Precision honed heavy wall tubing—6 to 1 safety factor.
- Spring loaded "V" packing on rod end gland.
- Key type stainless steel locking ring. Allows 360° orientation of pipe ports.

ROTARY TORQUE ACTUATOR PNEUMATIC-HYDRAULIC



- New design opportunities
- To 370° rotation as standard
- Safe, powerful torque
- Air, oil, gas, water operation
- Zero leakage

STANDARD ROTATIONS

0-100°	0-280°
0-190°	0-370°

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steel, 303 and 316 stainless steel and brass in ¼-, ½-, ¾-, 1-, 1½- and 2-in. sizes. Prices start at $10.20 for ¼-in. carbon steel valve. Hydromatics Inc, 5 Lawrence St, Bloomfield, NJ.

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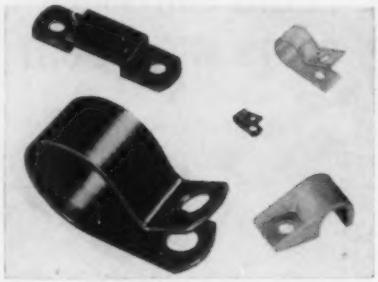

Nylon cable clamps . . .

range in size from 0.160 in. wide, 0.030 in. thick for close-quarter installation of small work to ⅜ in. wide, 0.070 in. thick for larger jobs. Smallest unit holds cable of less than 1/16-in. dia; largest accommodates cables or bundles up to 1¾ in. in dia. Recommended for service between −60 and 275 F when subjected to load. Said to be unaffected by petroleum oils and greases at temperatures up to 300 F. Weckesser Co Inc, Dept PE-1, 5701 Northwest Hwy, Chicago 46.

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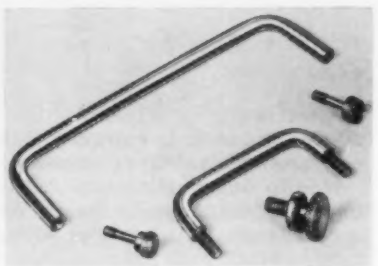

Rack and panel handles . . .

include clear anodized aluminum handle with brushed finish; standard round handle with 30° bend for crowded panels; handle which folds 90 or 180°; and outside threaded handle with threaded ferrule and nut. Latter three are available in polished chrome, nickel and black oxide. Round and folding handles are also available in stainless steel and aluminum. Vermaline Products Co, Franklin Lakes, NJ.

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Mylar tubes . . .

are available in range of ID's from 0.040 to 8 in. Wall thicknesses range from 0.001 to 0.050 in. in relationship to ID. Average min dielectric strength is 2500

v/mil and continuous heat resistance, 300 F. Rated Class B (266 F), tubes are impervious to common solvents, alcohol, naphtha, toluol and similar chemicals, as well as resistant to corrosion and fungus. Available in threaded forms for iron core coils, which can be supplied with polyester coating for protection against breakthrough caused by threading. Resinite Corp, Dept PE-1, 6984 N Central Park Ave, Chicago 45.

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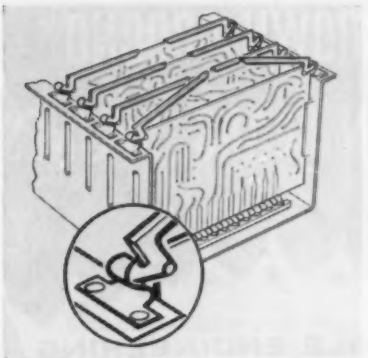

Printed circuit board fastener has lever which pivots from corner of circuit board and engages a spring attached to the chassis. Two fasteners are used for each board so that raising lever arms automatically ejects board from its socket. Lowering arm pushes board back toward socket, completing circuit and locking board in place. Fastener's 8 to 1 lever ratio enables replacement of boards in seconds. Southco Div, South Chester Corp, Lester, Penna.

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Coaxial cable connectors . . . with "crimp-on" construction, have only three handling parts and min 50-lb cable pull. Available in either weatherproof or nonweatherproof versions. Dage Electric Co Inc, 67 N 2nd St, Beech Grove, Ind.

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Variable-speed drive . . . available from 1 to 200 hp, is a static-powered unit which uses silicon diodes and saturable reactors to rectify current from in-plant ac to dc. The two work in combination with transistor-equipped power exciter to supply variable voltage. Drive comprises dc motor, operator's station and control cabinet, and in some sizes is 35% smaller than conventional units. Absence of rotating power unit provides vibrationless operation of control unit. Reliance Electric & Engineering Co, 24701 Euclid Ave, Cleveland 17.

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continued on page 97

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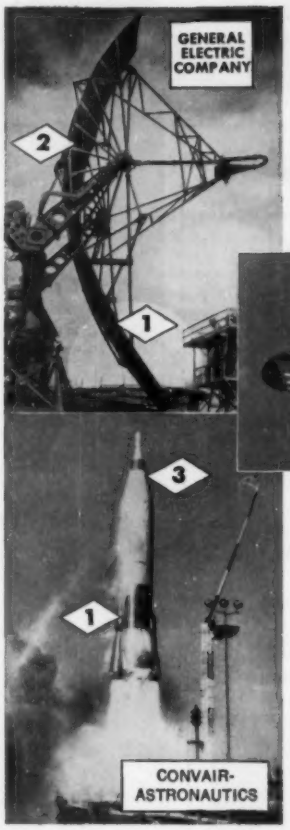

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ON MAGNESIUM—short immersion, room temperature solution, no electrical equipment. Corrosion protection relatively unaffected by high drying temperatures. Applicable to all alloys. Low electrical resistance. Color ranges from light gray to dark brown.

IRIDITE—a specialized line of chromate conversion coatings for non-ferrous metals. Easily applied at room temperatures with short immersion, manually or with automatic equipment. Forms a thin film which becomes an integral part of the metal. Cannot chip, flake or peel; special equipment, exhaust systems or highly trained personnel not required.

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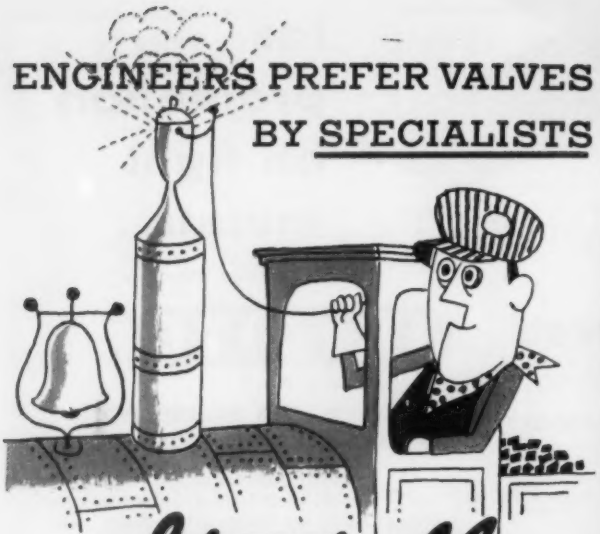

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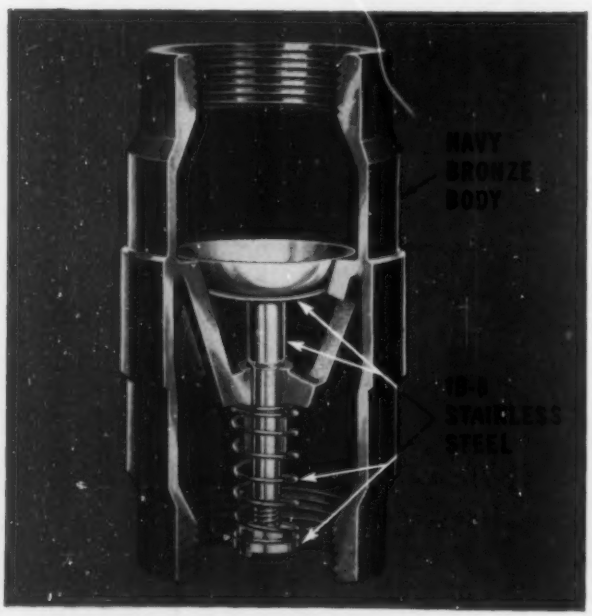

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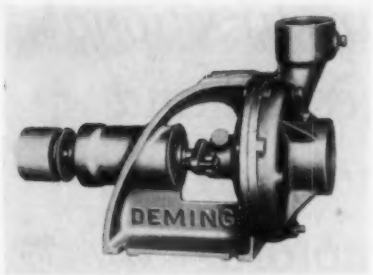

End-suction centrifugal pump uses double ball bearings and is equally suitable for belt or direct motor drive (can be used for booster operation when suction pressure does not exceed 25 lb). Capacity ranges from 10 to 300 gpm, and heads range to 150 ft. Semi-open impeller is mounted on stainless shaft with taper fit. Normally furnished for right-hand operation, but left-hand is available in all but 3-in. size. Deming Co, Salem, Ohio.

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Ac-operated brake . . . is flange-mounted and completely enclosed in a housing with torque ratings of 500, 750 and 1000 lb-ft. Said to have high thermal capacity and extremely low WK^2. Entire operating mechanism is attached to single plate, facilitating disassembly and assembly. Made of ductile iron. Stearns Electric Corp, 120 N Broadway, Milwaukee 2.

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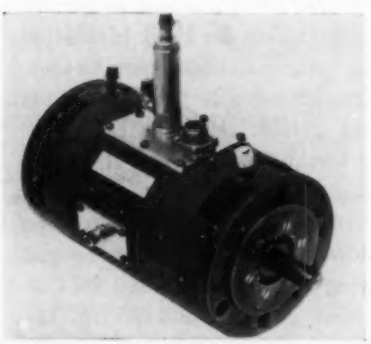

Pad-type torquemeter . . . has both electrical means for measuring torsional strain and mechanical assembly for providing that strain. Variable inductance transducers measure angular twist which is proportional to torque. This signal is fed through slip-ring-and-brush assembly, and output can be read on standard carrier amplifier equipment. Available models operate at speeds up to 20,000 rpm and sense torques from 0 to 50 in.-lb full scale through 0 to 12,000 in.-lb full scale. B & F Instruments Inc, 3644 N Lawrence St, Philadelphia 40.

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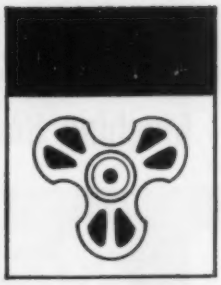
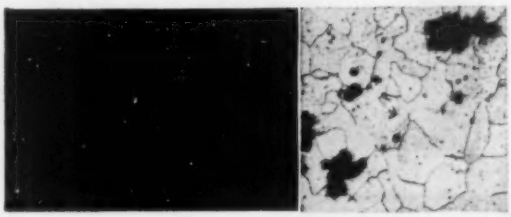


3-LOBE DESIGN

Exclusive M-D 3-lobe design adds strength—reduces torsion. Dynamically balanced rotor permits higher speeds —greater pressures.

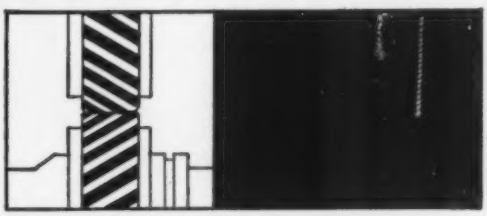


DUCTILE IRON

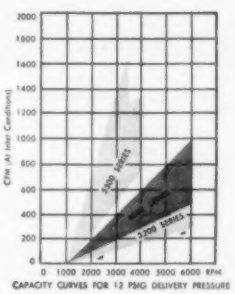
Only M-D uses ductile iron rotors. Only M-D rotors are cast with lobe and shaft integral—no pins to work loose. Makes M-D blowers safest at high speeds.

HELICAL GEARS

Every M-D blower shipped has a matched pair of crown-shaved, helical gears. Backlash tolerance is .0005" to .0015". No other blower matches M-D quality.

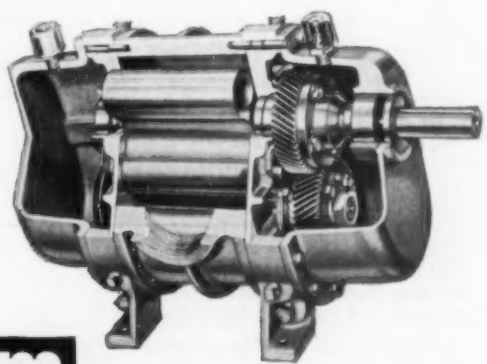


WHY M-D ROTARY POSITIVE BLOWERS DEVELOP HIGHER PRESSURES...



The unique combination of precision manufacture and modern design found only in M-D rotary positive blowers permits higher speed operation and higher pressures. For this reason M-D can furnish greater air flow at lower initial cost.

M-D blowers operate at wider pressure and speed ranges than any other rotary positive blower. Capacities of 30 production models range from 30 to 4,000 CFM, pressures to 15 PSIG single, 70 PSIG multi-stage.



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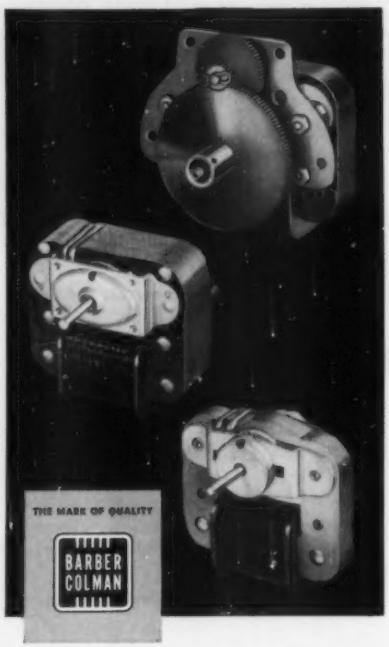

Outstanding for their high starting torque and low-inertia rotors. Precision-made for commercial and industrial applications such as appliances, vending machines, projection equipment, office machines, displays, toys, pumps, blowers, and fans. Shaded pole type, 115 volt a-c (220 volt optional) . . . up to 1/20 hp. Low noise level . . . long-life lubrication . . . high dielectric strength coils . . . stainless steel shafts . . . quality guaranteed!

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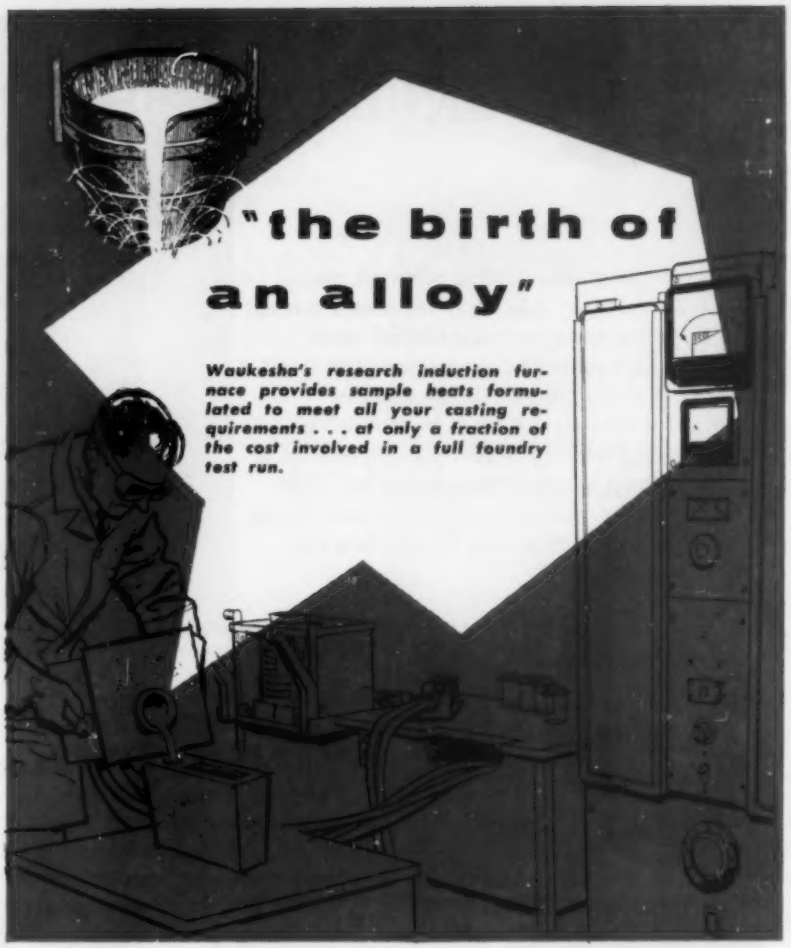
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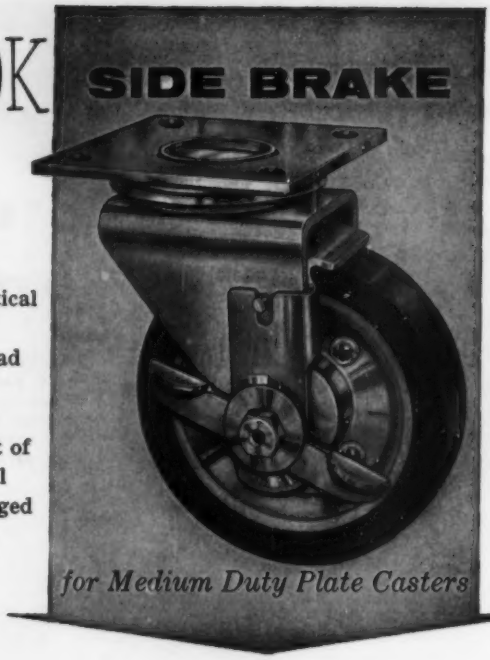
NEW J&J VERTILOK



To provide greater locking strength, the J & J "Vertilok" side brake features a vertical cam action and a specially formed brake shoe which contacts the maximum tire tread area. A slight press of the toe and the wheel is securely locked . . . or completely released. Provision is made for adjustment of the braking action to compensate for wheel or tire wear. Simplicity of design and rugged construction assure long, trouble-free life.

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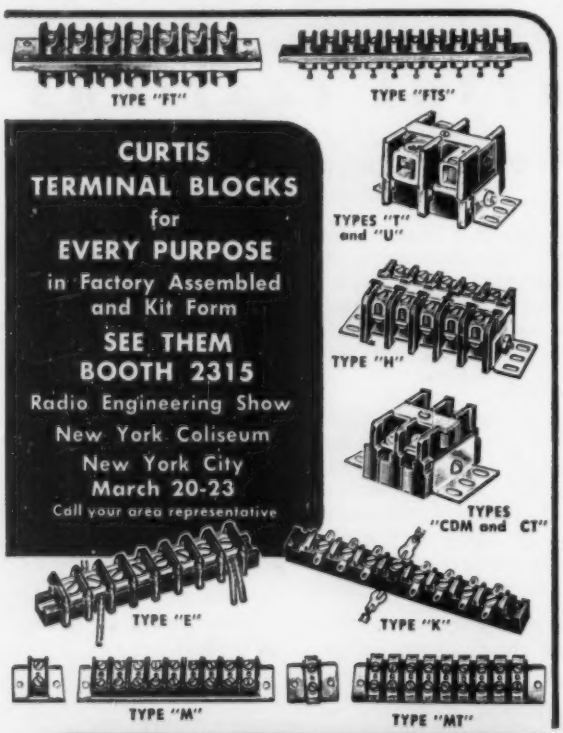
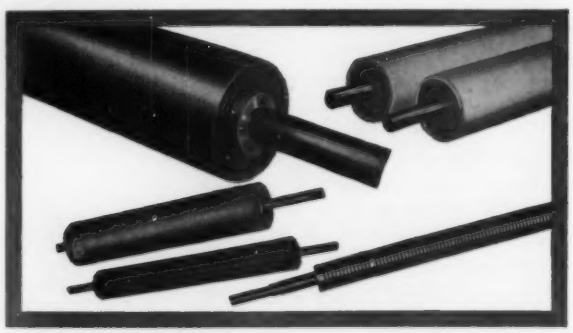


CURTIS DEVELOPMENT & MFG. CO.
3292 North 33rd Street, Milwaukee 16, Wisconsin



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DESIGN LITERATURE

Analogue Computation

STANLEY FIFER. McGraw-Hill Book Co, 330 W 42nd St, New York 36. Four volumes, 6 x 9, 1370 total pp. $39.50, the set.

The "ue" on the end of the word "analogue" hints at the kind of a book this is: stuffy. The author's competence is well established (he is president of Dian Laboratories Inc, a manufacturer of analog computers) and there is no doubt that he has been thorough. But because of his mathematical approach (he is also an ex-instructor of mathematics) the book serves more as textbook than as working guide to analog computation.

Which is not to say it's unnecessarily mathematical or overly detailed; it's just more than the average design engineer needs if he's interested only in how to solve complex problems on the analog computer. The author does have one unusual and helpful technique: he starts each chapter, and some of the subsections, with a brief summary of what is included and what will be proved. Though handled awkwardly at times ("We shall confine our attention in this chapter to . . .", "We shall prove . . .") the reader appreciates this attention to his interests.

The division among volumes is chosen on the basis of length rather than on content—each volume being about 350 pages. The volumes are not subdivided except by chapters. A description of the hardware is woven in with a discussion of the mathematics it simulates. Thus, a chapter on linear potentiometers is followed by a chapter on linear differential equations; and a chapter on function generators, by one on time-varying and nonlinear differential equations. Also covered in individual chapters are: amplifiers, multipliers, resolvers, recorders, transfer functions, error analysis, mechanical differential analyzers, partial differential equations, fourier analysis, noise, the adjoint method and special chapters on the dynamics of flight and advanced techniques.—CJL

The Arc Discharge

H de B KNIGHT. Chapman & Hall Ltd, 37 Essex St, WC 2 London, England, 8¾ x 5½, 444 pp. $8.60.

Arc-discharge electron tubes such as thyratrons, ignitrons and excitrons for the control of electrical power are described. Construction, operating characteristics, limitations and control are covered. Aim is to show the basis of the rating limitations specified by the manufacturers and also to give some guidance as to the behavior to be expected in new applications not covered by the ratings. This comprehensive survey is invaluable both as a primer and book of reference and contains a thorough index and bibliography.

The Extrusion of Metals (2nd Edition)

PEARSON & PARKINS. John Wiley & Sons, Inc, 440 Park Ave South, New York 16. 5½ x 8¾, 336 pp. $7.50.

Extrusion, a relatively new process, has become increasingly important in metal production, because it gives large reductions in cross-section from billet size to finished shapes. Although extrusion requires expensive dies, heavy equipment and large amounts of power, its high output justifies the cost. One important advantage—working the metal in compression—allows extrusion of many newer metals which are normally difficult to forge, roll or draw.

Although the book (a second edition) is a thorough treatment, it does not include one recent advance in the field—pelletizing magnesium before

continued on page 103

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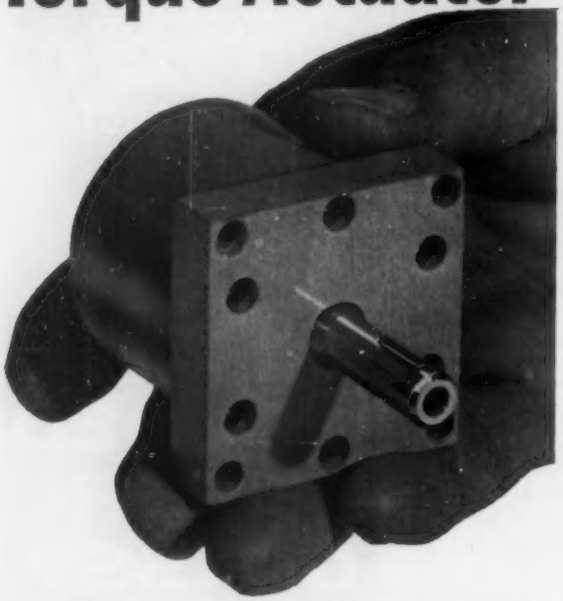

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extruding to give the finished product finer grain and better compressive properties. For details on this technique see PE—May 12 '58, p 80.

ABSTRACTS FROM THE LITERATURE

Man in Cold Places

The author discusses reactions of the body to cold, ways man counteracts cold and body damage caused by cold. He concludes that no one can predict the exact result of exposure to cold.

"Man in Cold Environments," by S. M. Horvath, the Lankenau Hospital. American Society of Mechanical Engineers paper 60-WA-240, 29 W 39th St, New York 18.

Molded-in Hinge

This paper is intended to impart an understanding of the principles, properties, basic design, and molding of polypropylene hinges. Several case histories are included to assist design engineers in technical consideration of applying this hinge to new products.

"The Molded-in Hinge in Polypropylene Components," by Russell D. Hanna, Plastics Technical Service Lab, Hercules Powder Co. Presented at 17th Annual Technical Conference, SPE, 65 Prospect St, Stamford, Conn.

Engineering in Magnetohydrodynamics

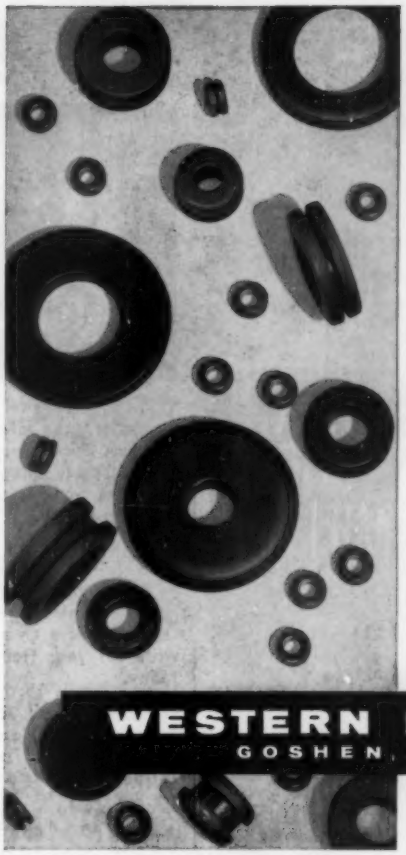
Magnetohydrodynamics offers the engineer innumerable challenges to design many new devices. Some of the more important applications are:

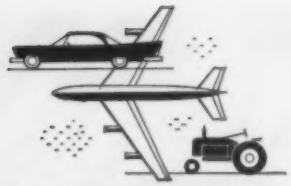
Materials science. In the past, it was difficult to find high-temperature sources, but now plasma dynamics has opened new vistas, because ionized gases occur at high temperatures and thus may be used to great advantage by the metallurgist.

Flow control. The flow of liquid metals such as molten sodium used in reactors necessitates unusual pumping, controlling and measurement techniques. Because a molten metal is electrically conducting, magnetohydrodynamics offers many practical solutions and some of these are being used widely.

Aerodynamics. Because the velocity and the temperature gradients in a conducting gas near a wall can be

continued on page 105





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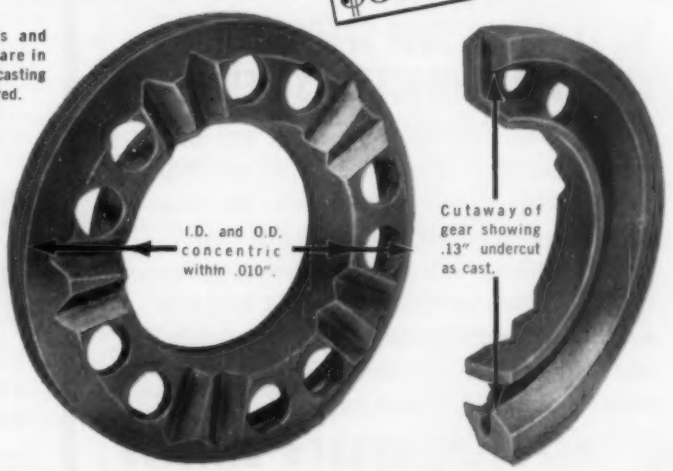

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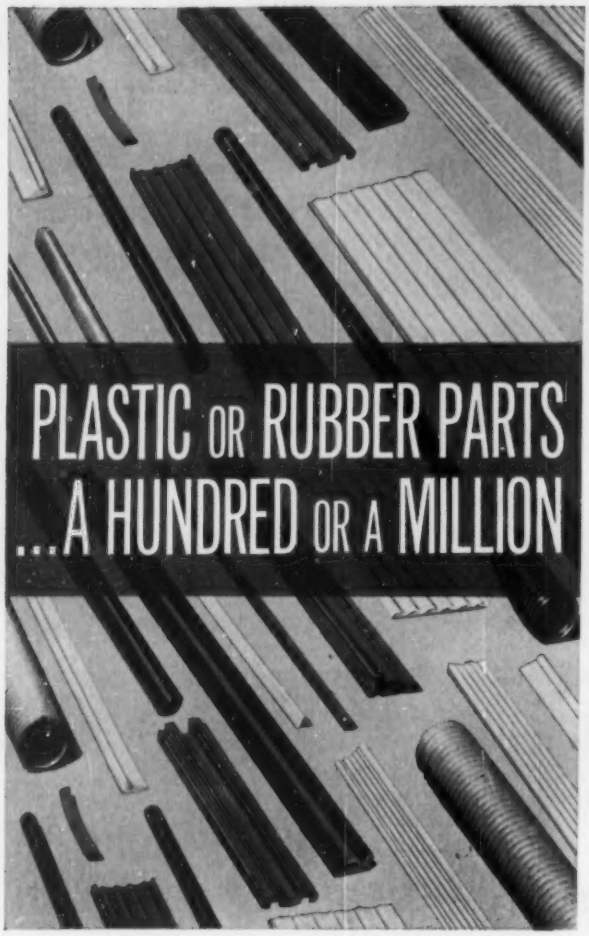

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3/16″	4400	4140	8240
1/4″	7700	7360	14720
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modified by the application of magnetic fields, magnetohydrodynamics is being studied widely by aerodynamicists.

Containment. Magnetohydrodynamics may be applied to advantage in fusion devices by pinching the extremely hot gases.

Propulsion and power generation. New types of propulsive devices are being studied and in the offing are engines which derive their propulsive power by accelerating plasma streams. Also under consideration are magnetohydrodynamic power generators, which may soon supply homes and factories with electricity.

"Foundations of Engineering Magnetohydrodynamics," Ali Bulent Cambel, Gas Dynamics Laboratory, Northwestern University, Evanston, Ill. Paper No. 312A. SAE. 435 Lexington Ave, New York 17.

CATALOGS AND BULLETINS

To obtain copies of literature described below, circle corresponding number on postcard inside back cover.

SILICONES—Booklet, 16 pp. Discusses uses for consumer and industrial products and suggests ways in which they can be adapted to new applications. Contains heat-aging curves and tables covering properties and features of silicone fluids, resins, rubber compounds, water repellents, antifoams and emulsions. Silicone Div, Union Carbide Corp, 270 Park Ave, New York 17.

Circle 350 on Reader Service Card

WELDED-DIAPHRAGM BELLOWS—Brochure 25-261, 8 pp. Underlines design and application data, including these subjects: basic diaphragm contours and their applications; attaching bellows; explanation and use of design curves; and bellows materials. Illustrated with photographs and spring rate and life-expectancy curves. Metal Bellows Corp, 3043 Mica Lane, Wellesley Hill 82, Mass.

Circle 351 on Reader Service Card

QUICK-DISCONNECT COUPLINGS—Bulletin 254, 8 pp. Along with cutaway views, explains connection methods and variations of three basic valving concepts to meet most fluid-line needs. Includes case histories on four fluid-line problems. Aeroquip Corp, Jackson, Mich.

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TEFLON GASKETS AND RINGS—Specification sheets, 4 pp. Contains military standards for retainer gaskets, packing backup and packing retainer rings.

continued on page 107

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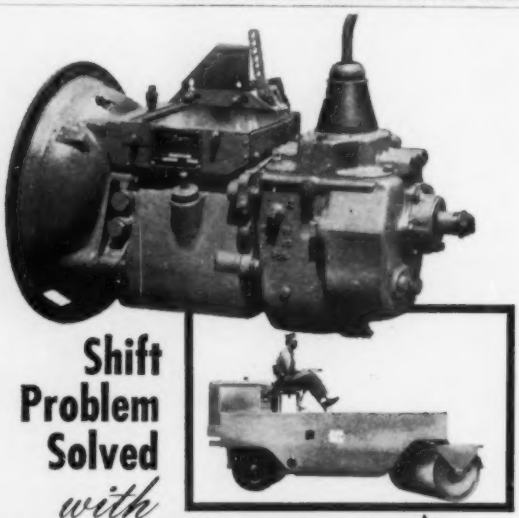

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Includes outline drawings, dash numbers and standard dimensions. Tetrafluor Inc, 343 Hindry Ave., Inglewood, Calif.

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PRECISION WIRE—Brochure, 8 pp. Tables and curves cover temperature resistance; specific resistance; resistance- and temperature-coefficient tolerances; yield strength and elongation vs diameter for varying temperatures; and other properties of nonmagnetic nickel-chromium alloy wire. Molecu Wire Corp, Eatontown-Freehold Pike, Scobeyville, NJ.

Circle 354 on Reader Service Card

PLASTIC SUBSTANCE FLOW BEHAVIOR—Pamphlet, 5 pp. Study by Dr A G Epprecht on viscous deformation of plastic substances, showing that rheological behavior of plastic substances can be measured successfully in rotational viscometers under several conditions. Drage Products Inc, 406 32nd St, Union City, NJ.

Circle 355 on Reader Service Card

THERMAL INSULATION—Catalog IN-244A, 64 pp. Contains application photos, available forms or types, advantages and specifications of insulation products for industrial and high-temp use; plumbing, heating and air conditioning; refrigeration; insulating firebrick and refractories; finishes and weatherproofing, etc. Johns-Manville Sales Corp, 22 E 40th St, New York 16.

Circle 356 on Reader Service Card

TUNNEL DIODE—Handbook, 48 pp. Details electrical and physical parameters, testing criteria and typical circuit applications, accompanied by humorously captioned silent-movie stills. Hoffman Electronics Corp, Semiconductor Div, 1001 N Arden Dr, El Monte, Calif.

Circle 357 on Reader Service Card

QUICK-CHANGE GEAR CHASSIS—Bulletin, 2 pp. Describes and illustrates how unit makes possible infinite range of ratios on any mechanism. Includes parts' specifications and prices. Foster & Allen Inc, 26 Commerce St, Chatham, NJ.

Circle 358 on Reader Service Card

SUBMINIATURE RF CONNECTORS—Catalog D2-1, 12 pp. Contains outline drawings and dimensions of approx sixty 50 and 75-ohm plugs, jacks, bulkhead receptables, feed-thrus, right-angle units, cable terminations, tee adaptors and printed wiring board units. Electrical and mechanical features of snap-in and crimp-type connectors are discussed and illustrated. Sealectro Corp, 139 Hoyt St, Mamaroneck, NY.

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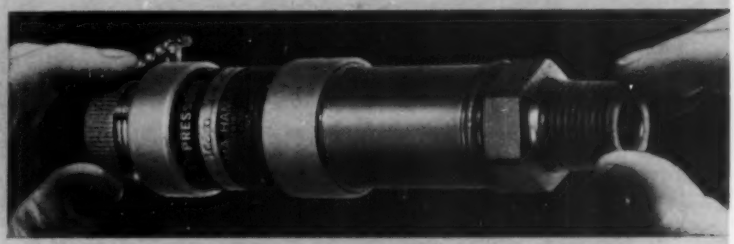

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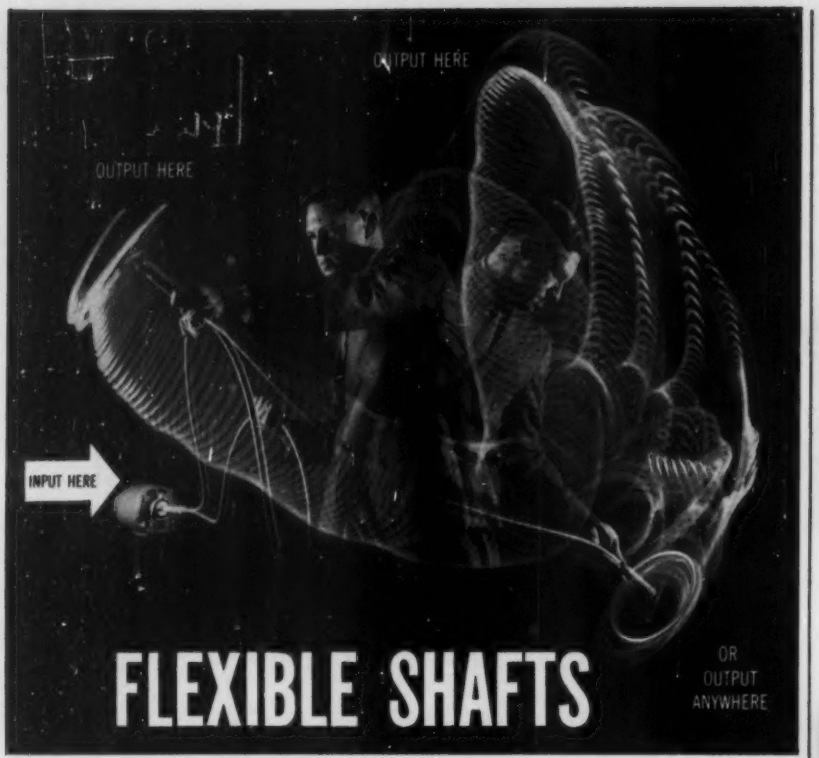

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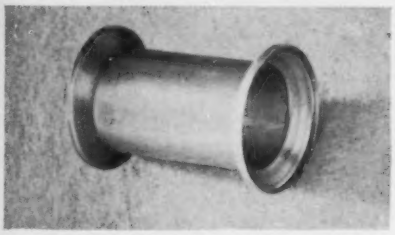

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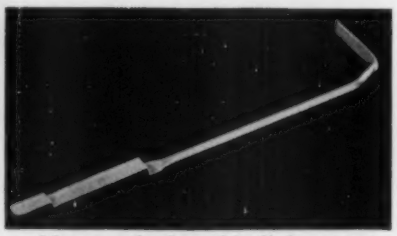

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REGULATORS AND CONTROL VALVES—Bulletin J-DI, 4 pp. Covers composition, properties and specifications of ductile iron valves and results of quench test on ductile iron. Table compares steel, cast iron and red brass with ductile iron. Six valves, including diaphragm-control device and piloted pressure regulator, are described and illustrated. OPW-Jordan Corp, 6013 Wiehe Rd, Cincinnati 13.

Circle 360 on Reader Service Card

TRACTION MOTORS—Bulletin GEA-7309, 4 pp. Lists features, ratings and dimensions of 6⅝-in. dia units for low-voltage dc electrical vehicles. Includes connection diagrams and motor-speed torque curves. General Electric Co, Schenectady 5, NY.

Circle 361 on Reader Service Card

CASTERS—Pocket-size catalog 1750, 16 pp. Tabulates wheel dia and face, rated capacity, wheel type, over-all height, and bolt-hole spacing of five series. Also gives information on floor protection, nonmarking and cushioning effects of each caster. Rapids-Standard Co Inc, 342 Rapistan Bldg, Grand Rapids 2, Mich.

Circle 362 on Reader Service Card

FOUR-LAYER DIODES—Catalog, 6 pp. Gives electrical specifications, operating characteristics and dimensional drawings of six series of four-layer, two-lead, silicon switches. Shockley Transistor, Unit of Clevite Transistor, Stamford Industrial Park, Palo Alto, Calif.

Circle 363 on Reader Service Card

CENTRIFUGAL PUMPS—Bulletin 3913, 4 pp. Carries performance tables and dimensional drawings of sizes 1 through 3-in. double ball bearing, end-suction units. Deming Co, Salem, Ohio.

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SYNCHRONOUS GENERATORS—Bulletin 2100-PRD-250, 2 pp. Describes, illustrates and gives electrical specifications of alternating current generators in ratings from 3.75 to 62.5 kva. Electric Machinery Mfg Co, Minneapolis 13.

Circle 365 on Reader Service Card

RUBBER PUSHBUTTON STATIONS—Bulletin B82, 4 pp. Presents construction and performance data and prices of eight models. Includes outline drawings. Joy Mfg Co, Electrical Products Div, 1201 Macklind Ave, St Louis 10.

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GENERAL-PURPOSE OSCILLOSCOPES—Booklet, 20 pp. Covers construction and performance characteristics and specifications of single-beam, dual-beam, dual-trace and rack-mount models.

continued on page 111

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For complete details and specifications on the new C-230 Utility Slide, request Engineering Data Sheet 1600.

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Switch Types	N.O., N.C., or double throw — no neutral position.
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Block diagram, curve tracings and photo of each model are included. Tektronix, Inc, PO Box 500 Beaverton, Ore.

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EFFECTS OF NUCLEAR RADIATION ON CIRCUITS—Booklet ETD 2564, 22 pp. Reviews known effects of pulse and steady-state radiation on circuits and components and outlines design considerations for minimizing these effects. Discusses high resistance to radiation shown by circuits made of evacuated, encapsulated ceramic and titanium components. General Electric Co, Receiving Tube Dept, Owensboro, Ky.

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ELECTRIC PLANTS—Catalog sheet, 2 pp. Describes and illustrates line, ranging from 500-w portable plant to 230,000-w diesel set. Condensed specifications show capacities, electrical details, engine characteristics and over-all dimensions. Onan Div, Studebaker-Packard Corp, 2515 University Ave SE, Minneapolis 14.

Circle 369 on Reader Service Card

TRACK-LAYING SUSPENSIONS—Booklet, 12 pp. Graphically illustrates engineering principles and discusses advantages as components of specialized hauling and transport equipment. Specifications and hauling capacities also are presented. Athey Products Corp, 5631 W 65th St, Chicago 38.

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PIPE AND TUBING MEASUREMENT—Bulletin 631, 16 pp. Supplies standard measurement methods and discusses both similarities and differences involved in measuring fittings and fluid-carrying lines. Dash-numbering systems also are explained. Illustrated with cutaway views of hoses and fittings. Aeroquip Corp, Jackson, Mich.

Circle 371 on Reader Service Card

HEAT CONTROL—First issue, Sarcoscope, external house organ, 16 pp. Contains articles citing performance of steam traps and strainers. Sarco Co Inc, 635 Madison Ave, New York 22.

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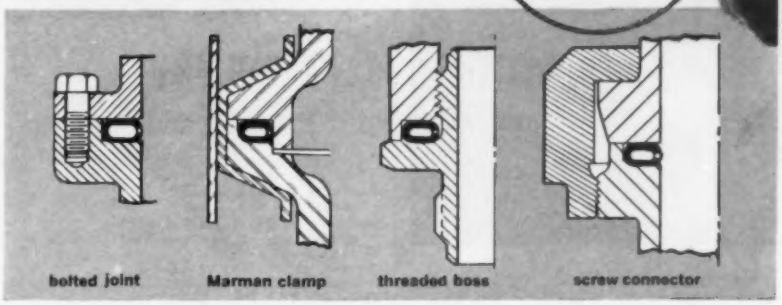

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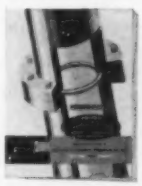

See United Metallic O-Ring Catalog in Sweet's Product Design File or write for Free Handbook

*Patents 2,809,269; 2,837,360
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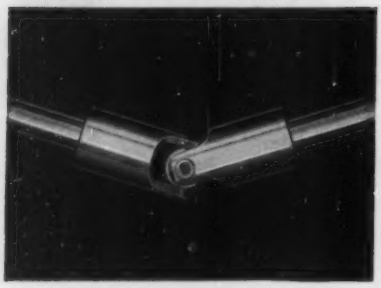

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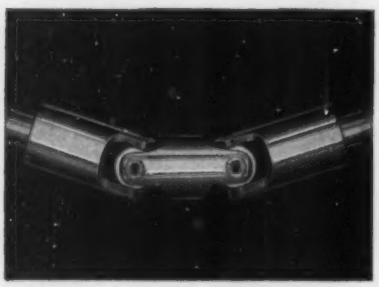

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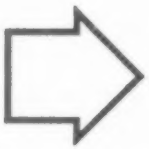

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320—Two Relays, Overload Protector

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307—Bar Switchlight
312—Ac-dc Power Relay
313—Miniature Liquid-in-glass Termostat
315—Decade Counter Tube
316—Digital Time and Frequency Meter
317—Miniature Contactor
318—Light Indicator Modules
320—Two Relays, Overload Protector
321—Miniature T Switch
322—Multicolor Ribbon Cable
323—Molded 1-in. Dia Tap Switch
328—Printed Circuit Board Fastener
329—Coaxial Cable Connectors

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324—Bar Stock Ball Valves
327—Mylar Tubes
331—End Suction Centrifugal Pump

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354—Precision Wire, 8 pp, Molecu Wire Corp.

NON-METALLIC MATERIALS, FINISHES
350—Silicones, 16 pp, Silicones Div, Union Carbide Corp.
355—Plastic Substance Flow Behavior, 5 pp, Drage Products Inc.
356—Thermal Insulation, 64 pp, Johns-Manville Sales Corp.

POWER TRANSMISSION
358—Quick Change Gear Chassis, 2 pp, Foster & Allen Inc.

MECHANICAL PARTS
351—Welded Diaphragm Bellows, 8 pp, Metal Bellows Corp.
353—Teflon Gaskets and Rings, 4 pp, Tetrafluor Inc.
356—Thermal Insulation, 64 pp, Johns-Manville Sales Corp.
362—Casters, 16 pp, Rapids-Standard Co Inc.
370—Track-laying Suspensions, 12 pp, Athey Products Corp.

MOTORS, ENGINES AND CONTROLS
361—Traction Motors, 4 pp, General Electric Co.
372—Heat Control, 16 pp, Sarco Co Inc.

ELECTRICAL, ELECTRONIC COMPONENTS
357—Tunnel Diode, 48 pp, Hoffman Electronics Corp.
359—Subminiature RF Connectors, 12 pp, Sealectro Corp.
363—Four-layer Diodes, 6 pp, Shockley Transistor, Unit of Clevite Transistor
365—Synchronous Generators, 2 pp, Electric Machinery Mfg. Co.
366—Rubber Pushbutton Stations, 4 pp, Joy Mfg. Co.
368—Effects of Nuclear Radiation On Circuits, 22 pp, General Electric Co.
369—Electric Plants, 2 pp, Onan Div, Studebaker-Packard Corp.
372—Heat Control, 16 pp, Sarco Co Inc.

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352—Quick Disconnect Couplings, 8 pp, Aeroquip Corp.
353—Teflon Gaskets and Rings, 4 pp, Tetrafluor Inc.
358—Regulators and Control Valves, 4 pp, OPW-Jordan Corp.
364—Centrifugal Pumps, 4 pp, Deming Co.
371—Pipe and Tubing Measurement, 16 pp, Aeroquip Corp.

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Name..... Title.....

Street.....

City..... Zone..... State.....

Company..... Major Product Manufactured.....

1	21	41	61	81	101	121	141	161	181	201	221	241	261	281	301	316	331	346	361	376
2	22	42	62	82	102	122	142	162	182	202	222	242	262	282	302	317	332	347	362	377
3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	318	333	348	363	378
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	319	334	349	364	379
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	320	335	350	365	380
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	321	336	351	366	381
7	27	47	67	87	107	127	147	167	187	207	227	247	267	287	307	322	337	352	367	382
8	28	48	68	88	108	128	148	168	188	208	228	248	268	288	308	323	338	353	368	383
9	29	49	69	89	109	129	149	169	189	209	229	249	269	289	309	324	339	354	369	384
10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	325	340	355	370	385
11	31	51	71	91	111	131	151	171	191	211	231	251	271	291	311	326	341	356	371	386
12	32	52	72	92	112	132	152	172	192	212	232	252	272	292	312	327	342	357	372	387
13	33	53	73	93	113	133	153	173	193	213	233	253	273	293	313	328	343	358	373	388
14	34	54	74	94	114	134	154	174	194	214	234	254	274	294	314	329	344	359	374	389
15	35	55	75	95	115	135	155	175	195	215	235	255	275	295	315	330	345	360	375	390
16	36	56	76	96	116	136	156	176	196	216	236	256	276	296						
17	37	57	77	97	117	137	157	177	197	217	237	257	277	297						
18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300						

REPRINTS

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583	584	585	586	587	588	589	590	591	592	593	594

*MULTIPLE PRODUCT ADS

Key No.	Specific Product

(please print or type) *If this is change of address, check box* ☐

Name..... Title.....

Street.....

City..... Zone..... State.....

Company..... Major Product Manufactured.....

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18	38	58	78	98	118	138	158	178	198	218	238	258	278	298						
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299						
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300						

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P70	P71	P72	P73	P75	P76	P77	P78	P79	580	581	582
583	584	585	586	587	588	589	590	591	592	593	594

*MULTIPLE PRODUCT ADS

Key No.	Specific Product

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Issue of March 20, 1961
PRODUCT ENGINEERING
Card expires May 19, 1961

FIRST CLASS
PERMIT No. 64
NEW YORK, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed in the United States

Postage Will Be Paid By Reader Service Department

Inquiries Services Department
PRODUCT ENGINEERING
330 West 42nd Street
New York 36, N. Y.

22 FL

Issue of March 20, 1961
PRODUCT ENGINEERING
Card expires May 19, 1961

FIRST CLASS
PERMIT No. 64
NEW YORK, N. Y.

BUSINESS REPLY MAIL
No Postage Stamp Necessary If Mailed in the United States

Postage Will Be Paid By Reader Service Department

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PRODUCT ENGINEERING
330 West 42nd Street
New York 36, N. Y.

22 FL

What synthetic sealing materials should I use—and when

Environmental conditions generally dictate the type of synthetic rubber for a specific oil sealing application.

Where temperature, shaft speed, runout, eccentricity, and lubricant type are "normal", standard Buna N synthetic rubber compounds are satisfactory. If, however, the application is "dry running", a compound must be selected that will operate satisfactorily with a very small amount of lubricant. If the application involves excessive abrasion, highly "loaded" compound stocks should be provided. At temperatures over 250° F polyacrylics or silicone compounds are indicated; if high temperature is accompanied by a solvent base or additive lubricant, polyacrylics are definitely preferred.

Thus many variables govern successful oil sealing. The chart below gives more data; for complete information from the world's foremost oil seal laboratories, call your National Seal engineer. He's in the Yellow Pages, under Oil Seals or O-Rings.

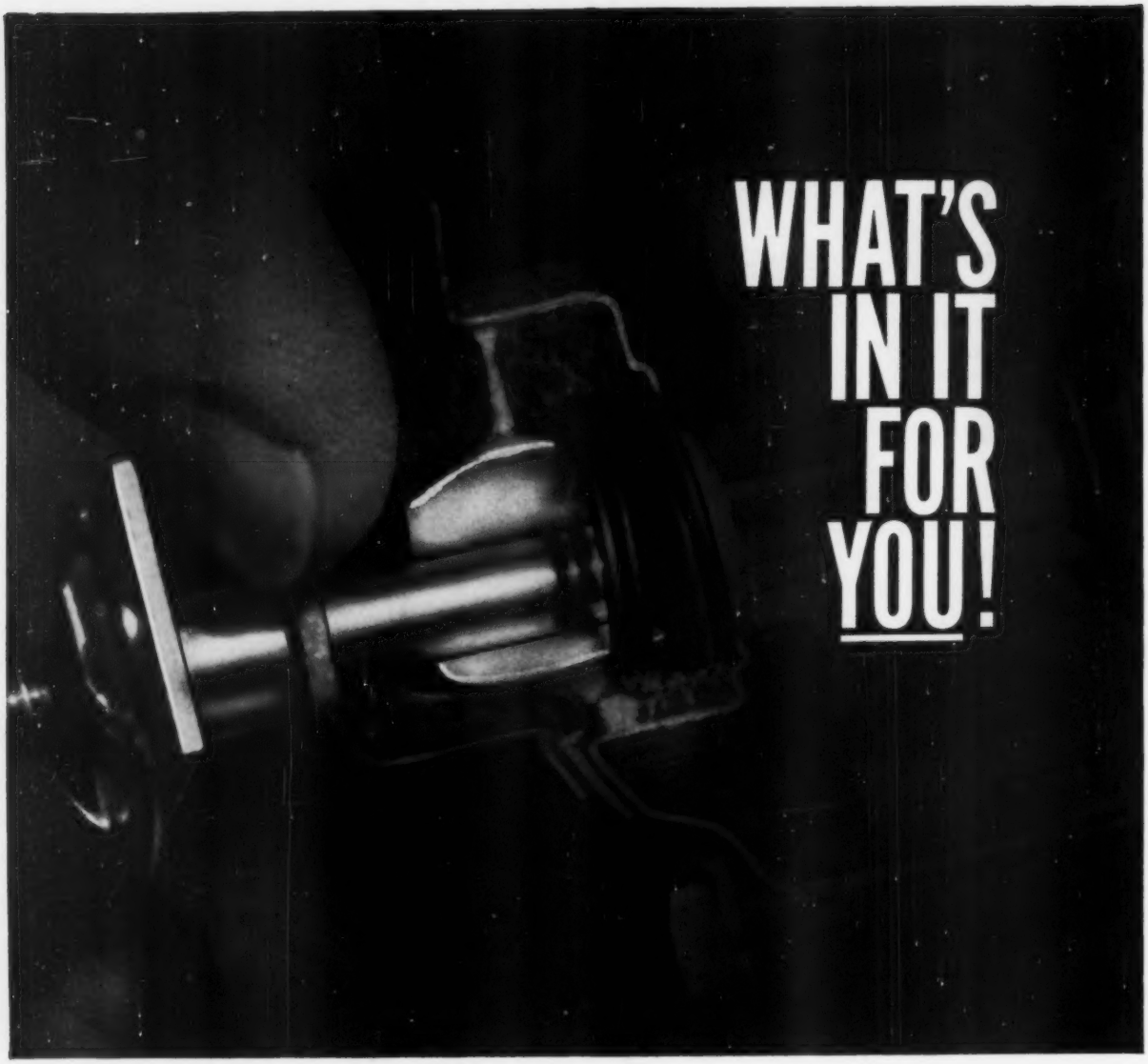
SYNTHETIC RUBBER COMPOUNDS | **RECOMMENDED APPLICATIONS**

Comp. No.	Base Polymer	Min/Max Operating Temperature	Life Index	Price Index	Automatic Transmissions	Pinions	Axle Seals	Engine Seals	Misc. Applications
B-63	Buna N	—40°F/225°F	100	100				Excellent for small gas engines.	Excellent for small non-spring loaded seals.
B-86	Buna N	—30°F/225°F	100	100		Satisfactory for medium temperature applications.	Truck and automotive rear axles. General use.	Satisfactory as general purpose material where temperature permits.	General purpose Buna N applications.
B-94	Buna N	—60°F/250°F	100	100					Excellent against aromatics and some military aircraft oils, fuels.
B-95	Buna N	—30°F/225°F	100	100					Good dry running compounds for applications requiring high durometer stock.
C-6	Buna N	—30°F/225°F	100	100			Excellent for semi-rough axles. Has good wear qualities.		Good for pressure seals due to high durometer and clean trimming.
L-28	Acrylon BA-12	—30°F/300°F	400	125	Good for temperature range indicated.	Satisfactory in single lip construction.	Sealed bearing high temperature applications.	Satisfactory for automotive use. High temperatures.	Satisfactory for high temperature general applications. Can be used with EP or GL-4 oils.
L-34	Hycar PA-21	0°F/300°F	400	115	Good for temperature range indicated.	Dual lip limited contact for high temperatures.	Sealed bearing high temperature applications.	Satisfactory for automotive use. High temperatures.	Satisfactory for high temperature general single or dual lips. Ok with EP or GL-4 oils.
S-48	Silicone*	—80°F/400°F	1500	150	Excellent high and low temperature life.	Silicone Compounds Not Recommended With EP Lubricants at high temperatures.		Excellent for general engine use. Suggested for premium gasoline and Diesel engines.	Excellent wide range material. Avoid use in EP and GL-4 oils.
S-49	Silicone*	—80°F/300°F	600	130	Good at high and low temperatures.			Very good for general engine use; premium gasoline and Diesel engines.	Very good wide range material. Avoid use in EP and GL-4 oils.

*Silicones require special stabilization for satisfactory use in aromatic oils at high temperatures.

NATIONAL SEAL
Division, Federal-Mogul-Bower Bearings, Inc.
GENERAL OFFICES: Redwood City, California
PLANTS: Van Wert, Ohio; Redwood City and Downey, California

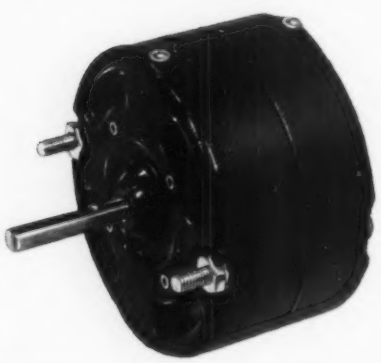
CIRCLE 202 ON READER SERVICE CARD



BEARING DESIGN OF
EMERSON ELECTRIC MOTORS

Is Self-Oiling, Self-Aligning to assure Free Starting and Smooth Operation at all times

—The bronze bearing in Emerson Electric Motors has thousands of tiny cells that cause the bearing to act as a metal sponge and feed the shaft journal a controlled flow of lubricant. In cooling, it draws off excess oil to give free starting at low temperatures. Self-Alignment minimizes friction and greatly increases motor life when you install *Emerson Electric Motors* in your appliances and equipment. Emerson Electric Motors are custom-engineered to meet your specific needs. Call us *today* . . . you'll like our way of doing business!



EMERSON ELECTRIC *of St. Louis • Since 1890*

DEPT. M21, 8100 FLORISSANT • ST. LOUIS 36, MO. • CO 1-1800

CIRCLE 203 ON READER SERVICE CARD